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# A MANUAL

OF

# PRACTICAL HYGIENE

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BY

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TO

The Memory

OF

SIDNEY LORD HERBERT OF LEA,

THIS IMPERFECT ATTEMPT

TO AID IN CARRYING OUT ONE OF HIS PLANS

FOR

THE BENEFIT OF THE BRITISH SOLDIER

IS DEDICATED.

# PREFACE TO THE FIFTH EDITION.

WHEN Dr Parkes died, no notes or instructions were found among his papers to indicate any special changes he intended making in the form or arrangement of this work. It may therefore be concluded that no material alteration was contemplated. The arrangement of the last edition has therefore been adhered to as closely as possible, although it has been necessary to re-write some portions—such as the chapter on Water Analysis—which required alteration, either on account of the introduction of improved methods of working, or because they were found practically inconvenient. Some new matter has been introduced from the comprehensive Reports on Hygiene published by Dr Parkes in the Army Medical Reports, and where new notes have been added they are generally distinguished by initials. Tables of useful numbers and of standard solutions are given in the Appendix for convenience of reference, and the Index has been considerably expanded. Although these alterations entail some little addition to its bulk, it is hoped that they will at the same time increase the usefulness of the Manual.

THE EDITOR.

JANUARY 1878.

# PREFACE TO THE FOURTH EDITION.

In compliance with requests made to me that I should put this edition in a form adapted for Civil Medical Officers of Health, I have not only re-written many chapters, as well as carefully revised all, but I have transferred the purely military part to the Second Book. In this way, without taking away the special character of the work, I have endeavoured to meet the desires expressed to me.

Although much new matter has been added, and some parts of the book has been greatly enlarged, I have exceeded the size of the last edition only by thirty-two pages, and though I have been obliged to sacrifice something to keep the size so nearly the same, I hope nothing material has been omitted.

I have thought it undesirable to occupy space by giving an abstract of the Sanitary Laws, as this is better done in special treatises, and as considerable changes may be made within a short period. The useful "Digest of Urban Sanitary Laws," lately published by the Local Government Board, also renders any legal details less necessary.

It is becoming every year more difficult, on account of space, to give the evidence on various questions connected with the causes and prevention of disease; I have therefore ventured to refer in many cases for fuller details of evidence to my Annual Reports on Hygiene, which have been published in the Army Medical Department Reports for the last twelve years.

June 1873.

# PREFACE TO THE FIRST EDITION.

THE Royal Commission appointed in 1857 to inquire into the sanitary condition of the army in England, prepared a new edition of the "Queen's Hospital Regulations," which was published by authority in 1859.*

The new Regulations entirely altered the position of the Army Medical Officer. Previously the Army Surgeon had been entrusted officially merely with the care of the sick, though he had naturally been frequently consulted on the preservation of health and the prevention of disease. But the Regulations of 1859 gave him an official position in this direction, as he is ordered "to advise commanding officers in all matters affecting the health of troops, whether as regards garrisons, stations, camps, and barracks, or diet, clothing, drill, duties, or exercises" (p. 7).

The Commission also recommended that, to enable the Army Surgeon to do this efficiently, an Army Medical School should be established, in which the "specialties of military medicine, surgery, hygiene, and sanitary science" might be taught to the young medical officers entering the army.

This work is an attempt to carry out the wishes of the Commissioners as regards sanitary science, by providing a text-book of Hygiene, illustrated by examples drawn from army life, for the gentlemen attending the Army Medical School.

The Official Medical Regulations have been taken as the basis of the work. I have endeavoured to see what the Regulations demand from the medical officers of the army, and what are the duties they chiefly have to do, and then to explain how the Regulations are to be carried out. In writing this work I have had to deal only with one sex, a certain age, and a particular trade; but as the general principles of hygiene are tolerably fully discussed, I have thought it entitled to be called a work on general hygiene.

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* "Regulations for the Duties of Inspectors-General and Deputy-Inspectors-General, and for the Duties of Staff and Regimental Medical Officers, &c.," 1859. This work is also termed, for shortness, "Medical Regulations."

The work is divided into two books: in the First I have arranged the chief subjects of hygiene in what is, for my purpose, the most convenient order, and have illustrated them by examples drawn from army life. I have also included some other topics, such as meteorology and statistics, which it is important medical officers should learn. In these several chapters I have thought constantly on what would be useful to army surgeons, who are often far from all books, or possibility of reference. So that, in some parts, I have endeavoured to make the book one of reference, though I have been obliged to compress it to the greatest degree. In the Second Book, the service of the soldier is more particularly described.

To enable medical officers to perform the chemical processes required in the analyses of water and air, and in the examination of food, the Director-General has recommended, and Lord de Grey has been pleased to sanction, the issue of a small box, containing sufficient apparatus and reagents for these processes, and this will be issued to the several stations on demand. After much consideration, I have adopted the French weights and measures, as being more convenient for volumetric analyses, of which considerable use is made. In chemistry the battle of the standards is over, and the simplicity of the French weights is such that even those who are not at first acquainted with them will, in a very short time, find no difficulty in using them. I have made the chemical directions as simple as possible, and have thought it best to use the old equivalents and notation.*

I have to thank my friend, Dr Maddox, for very kindly drawing for me all but two of the microscopic objects; his drawings have been very carefully engraved on copper or wood by Mr Bagg. I must express my obligations to the Council of the Royal United Service Institution for permitting me to use the stone with the lithographs of knapsacks, employed in illustration of Dr Maclean's paper, published in the 10th volume of the Journal of the Council.†

I have to thank also my friends, Dr Sutherland and Dr François de Chaumont, for many valuable suggestions.

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* In the later editions the new notation was adopted.

† This plate has been left out of the later editions.

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## CORRECTIONS AND ADDITIONS.

Page 18, line 8 from bottom (footnote), *for* "sample" *read* "samples."

Page 105, line 6 of column of figures in table, *for* "9·5621" *read* "0·5621."

Page 191, line 26, *for* "so called," *read* "to call."

Page 267, Milk. A further corroboration of the transmission of Enteric Fever through milk is given in Dr Russell's Report on the epidemic in Hillhead, a western suburb of Glasgow, December 1877.—See *British Medical Journal*, January 19, 1878, page 101.

## DIRECTIONS TO BINDER.

| | |
|---|---|
| Plates I. to IV. . . . . . . | to face page 66. |
| Plate V. . . . . . . | ,, 99. |
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| Plate VII. . . . . . . | ,, 276. |
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| Plate IX. . . . . . . | ,, 465. |

# INTRODUCTION.

HYGIENE is the art of preserving health; that is, of obtaining the most perfect action of body and mind during as long a period as is consistent with the laws of life. In other words, it aims at rendering growth more perfect, decay less rapid, life more vigorous, death more remote.

This art has been practised from the earliest times. Before Hippocrates there were treatises on hygiene, which that great master evidently embodied in his incomparable works. It was then based on what we should now call empirical rules—viz., simply on observations of what seemed good or bad for health. Very early, indeed, the effects of diet and of exercise were carefully noticed, and were considered the basis of hygiene.* Hippocrates, indeed, appears to have had a clear conception of the relation between the amount of food taken and of the mechanical energy produced by it; at least, he is extremely careful in pointing out that there must be an exact balance between food and exercise, and that disease results from excess either way.

The effects on health of different kinds of air, of water, and to some extent of soils, were also considered at a very early date; though naturally the ignorance of chemistry prevented any great advance in this direction. Hippocrates summed up the existing knowledge of his time on the six articles, which in after-days received the absurd name of the "Non-naturals." † The six articles, whose regulation was considered indispensably necessary to the life of man, were—air, aliment, exercise and rest, sleep and wakefulness, repletion and evacuation, the passions and affections of the mind.

With the exception of the attempts of the alchemists, and of the chemical physicians, to discover some agent or drug which might increase or strengthen the principle of life,‡ the practice of hygiene remained within the same limits until physiology (the knowledge of the laws of life) began to be studied. Hygiene then began to acquire a scientific basis. Still retaining its empirical foundation drawn from observation, it has now commenced to apply the physiological discoveries to the improvement of health, and to test the value of its own rules by this new light. It is now gradually becoming an art based on the science of physiology, with whose progress its future is identified.

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* Herodicus, one of the preceptors of Hippocrates, was the first to introduce medicinal gymnastics for the improvement of health and the cure of disease; though gymnastics in training for war had been used long before. Plutarch says of him, that labouring under a decay which he knew could not be perfectly cured, he was the first who blended the gymnastic art with physic, in such a manner as protected to old age his own life, and the lives of others afflicted with the same disease. He was censured by Plato for keeping alive persons with crazy constitutions.—*Mackenzie on Health.*

† This title originated in a sentence of Galen, and was introduced into use by the jargon of the Peripatetic school. It was employed in all treatises on hygiene for probably nearly 1500 years.

‡ It was when chemistry was being rudely studied by the alchemists that an entirely different school of hygiene arose. The discovery of chemical agents, and the great effect they produce on the body, led to the notion that they could in some way aid the forces of life, and insure a prolonged, if not an eternal youth, and a life of ages instead of one of years. This belief, the

But the art of hygiene has at present still another object. If we had a perfect knowledge of the laws of life, and could practically apply this knowledge in a perfect system of hygienic rules, disease would be impossible. But at present disease exists in a thousand forms, and the human race languishes, and at times almost perishes, under the grievous yoke. The study of the causes of disease is strictly a part of physiology,* but it can only be carried out by the practical physician, since an accurate identification of the diseases is the first necessary step in the investigation of causes.

The causes being investigated, the art of hygiene then comes in to form rules which may prevent the causes or render the frame more fitted to bear them; and as in the former case it was the exponent of physiology, in this case it becomes the servant of the pathologist.

Taking the word hygiene in the largest sense, it signifies rules for perfect culture of mind and body. It is impossible to dissociate the two. The body is affected by every mental and moral action; the mind is profoundly influenced by bodily conditions. For a perfect system of hygiene we must combine the knowledge of the physician, the schoolmaster, and the priest, and must train the body, the intellect, and the moral soul in a perfect and balanced order. Then, if our knowledge were exact, and our means of application adequate, we should see the human being in his perfect beauty, as Providence, perhaps, intended him to be; in the harmonious proportions and complete balance of all parts, in which he came out of his Maker's hands, in whose divine image, we are told, he was in the beginning made.

But is such a system possible?

---

natural result of the discovery of new powers, has not yet entirely died out; and while there are some who still look to every fresh agent as possibly containing "the balsam of life," there are also still enthusiasts who search the mystic tomes of the alchemists or the Rosicrucians, in the faith that, after all, the great secret was really found. It may be worth while to consider the idea which underlaid the dreams of the alchemists. Life was looked on as an entity or principle liable to constant waste, and to eventual expenditure. If some agent could be found to arrest the waste, to crystallise, as it were, the tissues in their full growth and vigour, decay, it was conceived, would be impossible, and youth would be eternal. In other cases, it was supposed that the agent would itself contain the principle of life, and therefore would at once restore destroyed health, and recall again departed youth. We now know this idea to be wrong in every point. The constant decay the alchemists sought to check is life itself, for life is but incessant change, and what we call decay is only a metamorphosis of energy. To arrest the changes in the body for one single moment would be death, or, short of death, it would be lessening of the energy which is the expression of life. Nor is there any hope that the extension of the period of vital energy can ever be accomplished except by improving the nutrition of the tissues. Here, indeed, it is just possible that, in time to come, drugs will aid Hygiene, either by better preparing food for the purposes of nutrition, or by removing or preventing those chemical changes in the tissues which we call decay. But at present, certainly, no rules can be laid down for the use of drugs in hygiene, except in that debateable land which lies between hygiene and the practice of medicine, that is, in that uncertain region which we do not like to call disease, and yet which is not health.

* Physiology and pathology are, in fact, one; normal and abnormal life, regular and irregular growth and decay, must be studied together, just as, in fact, human physiology is imperfect without the study of all the other forms of life, animal and vegetable, which are in the world. Separated for convenience, these various studies will finally converge.

Is there, or will there ever be, such an art, or is the belief that there will be, one of those dreams which breathe a blind hope into us, a hope born only of our longings, and destined to die of our experience? And, indeed, when we look around us and consider the condition of the world—the abundance of life, its appalling waste; the wonderful contrivances of the animal kingdom, the apparent indifference with which they are trampled under foot; the divine gift of mind, its awful perversion and alienations; and when, especially, we note the condition of the human race, and consider what it apparently might be, and what it is; its marvellous endowments and lofty powers; its terrible sufferings and abasement; its capacity for happiness, and its cup of sorrow; the heavenly boon of glowing health, and the thousand diseases and painful deaths,—he must indeed be gifted with sublime endurance or undying faith who can still believe that out of this chaos order can come, or out of this suffering happiness and health.

In the scheme of Providence it may not be meant that man shall be healthy. Diseases of mind and of body may be the cross he has to bear; or it may be the evil against which he has to struggle, and whose shackles he is finally to unloose. The last disease will disappear, we may believe, only when man is perfect; and as in the presence of the Saviour all disease was healed, so, before perfect virtue, sorrow and suffering shall fade away. Whether the world is ever to see such a consummation no man can say; but as ages roll on, hope does in some measure grow. In the midst of all our weaknesses, and all our many errors, we are certainly gaining knowledge, and that knowledge tells us, in no doubtful terms, that the fate of man is in his own hands.

NAWAB SALAR JUNG BAHADUR

It is undoubtedly true that we can, even now, literally choose between health or disease; not, perhaps, always individually, for the sins of our fathers may be visited upon us, or the customs of our life and the chains of our civilisation and social customs may gall us, or even our fellow-men may deny us health, or the knowledge which leads to health. But as a race, man holds his own destiny, and can choose between good and evil; and as time unrolls the scheme of the world, it is not too much to hope that the choice will be for good.

Looking only to the part of hygiene which concerns the physician, a perfect system of rules of health would, I conceive, be best arranged in an orderly series of this kind.

The rules would commence with the regulation of the mother's health while bearing her child, so that the growth of the new being should be as perfect as possible. Then, after birth, the rules (different for each sex at certain times) would embrace three epochs;* of growth (including infancy and youth); of maturity, when for many years the body remains apparently stationary; of decay, when, without actual disease, though, doubtless, in consequence of some chemical changes, molecular feebleness and death commence in some part or other, forerunning general decay and death.

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* First expressly noted by Galen.

In these several epochs of his life, the human being would have to be considered—

1*st*, In relation to the natural conditions which surround him, and which are essential for life, such as the air he breathes; the water he drinks; his food, the source of all bodily and mental acts; the soil which he moves on, and the sun which warms and lights him, &c.; in fact, in relation to nature at large.

2*d*, In his social and corporate relations, as a member of a community with certain customs, trades, conditions of dwellings, clothing &c.; subjected to social and political influences, sexual relations, &c.

3*d*, In his capacity as an independent being, having within himself sources of action, in thoughts, feelings, desires, personal habits, all of which affect health, and which require self-regulation and control.

Even now, incomplete as hygiene necessarily is, such a work would, if followed, almost change the face of the world. But would it be followed?

In some cases the rules of hygiene could not be followed, however much the individual might desire to do so. For example, pure air is a necessity for health; but an individual may have little control over the air which surrounds him, and which he must draw into his lungs. He may be powerless to prevent other persons from contaminating his air, and thereby striking at the very foundation of his health and happiness. Here, as in so many other cases which demand regulation of the conduct of individuals towards each other, the State steps in for the protection of its citizens, and enacts rules which shall be binding upon all. Hence arises what is now termed "State Medicine," a matter of the greatest importance. The fact of "State Medicine" being possible, marks an epoch in which some sanitary rules receive a general consent, and indicates an advancing civilisation. Fear has been expressed lest State Medicine should press too much on the individual, and should too much lessen the freedom of personal action. This, however, is not likely, as long as the State acts cautiously, and only on well-assured scientific grounds, and as long as an unshackled Press discusses with freedom every step.*

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* A watchful care over the health of the people, and a due regulation of matters which concern their health, is certainly one of the most important functions of Government. The fact that, in modern times, the subject of hygiene generally, and State Medicine in particular, has commenced to attract so much the public attention, is undoubtedly owing to the application of statistics to public health. It is impossible for any nation, or for any Government, to remain indifferent when, in figures which admit of no denial, the national amount of health and happiness, or disease and suffering, is determined. The early Statistical Reports of the Army by Tulloch, Marshall, and Balfour, directed attention to the importance of this matter. The establishment of the Registrar-General's office in 1838, and the commencement of the system of accurately recording births and deaths, will hereafter be found to be, as far as the happiness of the people is concerned, one of the most important events of our time. We owe a nation's gratitude to the Registrar-General for the persistence with which he has used his official position for the public good, and to his able coadjutors, especially to him to whose sagacity the chief fruits of the inquiry are due, to William Farr.

Another action of the Government in our day was scarcely less important. It is impossible to overrate the value of the Government Inquiry into the Health of Towns, and of the country generally, commenced more than a quarter of a century ago by Edwin Chadwick, Southwood Smith, Neil Arnott, Sutherland, Guy, Toynbee, and others, and which has, in fact, been continued ever since, and is now vigorously carried on by the official successor of these pioneers, the medical officer to the Privy Council, Mr Simon. Consequent on this movement came the appointment of medical officers of health to the different towns and parishes. The reports published by many of these gentlemen (Letheby, Dundas Thomson, Buchanan, Lankester, Hillier, Ballard, and many others) have greatly advanced the subject, and have done much to diffuse a knowledge of hygiene among the people, and at the same time to extend and render precise our knowledge of the conditions of national health. When the effect of all these

There are, however, some cases in which the State cannot easily interfere, though the individual may be placed under unfavourable hygienic conditions by the action of others. For example, in many trades, the employed are subjected to danger from the carelessness, or avarice, or ignorance of the employers. Every year the State is, however, very properly more and more interposing and shielding the workman against the dangers which an ignorant or careless master brings on him.

But in other cases the State can hardly interpose with effect; and the growth of sanitary knowledge, and the pressure of public opinion, alone can work a cure, as, for example, in the case of the dwellings of our poorer classes. In many parts of the country the cottages are unfit for human beings; in many of our towns, the cupidity of builders runs up houses of the most miserable structure, for which there is unhappily no lack of applicants; or masters oblige their men to work in rooms, or to follow plans which are most detrimental to health.

But even in such cases it will, I believe, be always found that self-interest would really indicate the course which is one of the foremost rules of religion. viz., that we should do for our neighbours as for ourselves. Analyse also the effect of such selfishness and carelessness as I have referred to on the nation at large, and we shall find that the partial gain to the individual is far more than counterbalanced by the injury to the State, by the discontent, recklessness, and indifference produced in the persons who suffer, and which may have a disastrous national result. It is but too commonly forgotten that the whole nation is interested in the proper treatment of every one of its members, and in its own interest has a right to see that the relations between individuals are not such as in any way to injure the well-being of the community at large.

In many cases, again, the employer of labour finds that, by proper sanitary care of his men, he reaps at once an advantage in better and more zealous work, in fewer interruptions from ill health, &c., so that his apparent outlay is more than compensated.

This is shown in the strongest light by the army. The State employs a large number of men, whom it places under its own social and sanitary conditions. It removes from them much of the self-control with regard to hygienic rules which other men possess, and is therefore bound by every principle of honest and fair contract to see that these men are in no way injured by its system. But more than this: it is as much bound by its self

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researches and measures develops itself, it will be seen that even great wars and political earthquakes are really nothing in comparison with these silent social changes. Even now legislation, though fragmentary and in some respects contradictory, is beginning to exert a deep influence. In the last few years several important Acts have been passed, viz., the Sanitary Act (7th August 1866), and the Amended Sanitary Act (July 1868); the Public Health (Scotland) Act (August 1867); the Act for providing better Dwellings for Artisans and Labourers (July 1868), and the former Acts on the same subject in 1866 and 1867: the Sewage Utilisation Act (August 1867). The Public Health Act of 1872 has advanced the subject another stage, and though some dissatisfaction has been expressed at its mode of working, there seems little doubt that its ultimate effect will be far deeper and more useful than appears at first sight. Legislation, and action based on legislation, can only proceed slowly, and we must be satisfied if there be a continual advance, though it may not be so rapid as some desire.*

* More recently the Public Health Act of 1875 has been passed, as well as the Amended Adulteration Act the Rivers Pollution Act, and others.

interest. It has been proved over and over again that nothing is so costly in all ways as disease, and that nothing is so remunerative as the outlay which augments health, and in doing so, augments the amount and value of the work done.

It was the moral argument as well as the financial one which led Lord Herbert to devote his life to the task of doing justice to the soldier, of increasing the amount of his health, and moral and mental training, and, in so doing, of augmenting not only his happiness, but the value of his services to the country. And by the side of Lord Herbert in this work was one whose name will ever be dear to the country, and whose life, ever since that memorable winter at Scutari in 1855, has been given up entirely to the attempt to improve the condition of the soldier.

This book has been written to assist in carrying out one of Lord Herbert's plans, and in accordance with his wish, and with that of Lord de Grey, his friend, coadjutor, and successor.

It has, therefore, been sketched on a narrower basis than the longer treatise indicated above, which would have to deal with both sexes, all ages, and various trades and conditions.

Although, however, as dealing with Military Hygiene, and drawing its chief examples from the soldier's life, it is a work on Army sanitation, it yet includes the great principles of hygiene applicable to all men—principles which, though here stated necessarily in the briefest and barest way, are, I am persuaded, fraught with benefit to all men, if they are properly interpreted and faithfully applied.

# BOOK I.

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## CHAPTER I.

## WATER.

THE supply of wholesome water in sufficient quantity is a fundamental sanitary necessity. Without it injury to health inevitably arises, either simply from deficiency of quantity, or more frequently from the presence of impurities. In all sanitary investigations, the question of the water-supply is one of the first points of inquiry, and of late years quite unexpected evidence has been obtained of the frequency with which diseases are introduced by the agency of water. In such an investigation, if the headings of the sub-sections of this chapter are followed, and the facts are noted under each heading in order, it will be hardly possible to overlook any condition which may have affected health. The order of investigation would be as follows:—Quantity of water per head; how is it collected; stored; distributed; what is its composition; is it wholesome water at its source and throughout, or has it been contaminated at any point of its distribution; what are the effects presumed to arise from it?*

### SECTION I.

### ON THE QUANTITY AND SUPPLY OF WATER.

#### SUB-SECTION I.—1. QUANTITY OF WATER FOR HEALTHY MEN.

In estimating the quantity of water required daily for each person, it is necessary to allow a liberal supply. There should be economy and avoidance of waste; but still, any error in supply had far better be on the side of excess. In England many poor families, either from the difficulty of obtaining water, or of getting rid of it, or from the habits of uncleanliness thus handed down from father to son, use an extremely small amount. It would be quite incorrect to take this amount as the standard for the community at large, or even to fix the smallest quantity which will just suffice for moderate cleanliness. It is almost impossible to give a definition of cleanliness, nor perhaps is it necessary, since there is a general understanding of what is meant.

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* *Army Regulations on the subject of Water.*—The Regulations for the Medical Department of Her Majesty's Army frequently refer to the supply of water. In Part II., Section i., paragraph 6 (issued as a circular July 1875, pending the complete issue of the Revised Regulations) the Surgeons General and Deputy Surgeons General are directed to "ascertain that the water-supply is good and abundant, and perfectly protected from pollution." Also, "that the means of ablution and cleanliness are sufficient and made use of by the men." In the Sanitary Regulations (army circular, December 1876) Section ii. paragraph 6, the medical officer in charge of troops is ordered to examine, from time to time, "the quality and amount of drinking-water," and to ascertain that there is "no soakage from latrines, cesspools, drains, or other sources of impurity." He is also ordered to inspect the lavatories and baths. In Sections vi. and vii. the same supervision over the water-supply of camps and garrisons and transport ships is enjoined.

When an army takes the field a Sanitary Officer is appointed, and he examines into all sanitary points, including the water-supply. (Section viii. paragraph 63.)

In the quarterly and annual reports the water-supply has to be considered, in common with other sanitary conditions, including "the sources, quality, and quantity of the water-supply, and whether it is wholesome, and what means of purification are in use, if such be necessary." Also, "Baths and lavatories, their conditions, and if sufficient for cleanliness for troops and sick; whether there are bathing parades and how often a week."

It must be clearly understood for what purposes water is supplied. It may be required for drinking, cooking, and ablution of persons, clothes, utensils, and houses; for cleansing of closets, sewers, and streets; for the drinking and washing of animals, washing of carriages and stables; for trade purposes; for extinguishing fires; for public fountains or baths, &c.

In towns supplied by water companies, the usual mode of reckoning is to divide the total daily supply in gallons by the total population, and to express the amount per head per diem.

The following are some of the gross amounts used at the present time for all the above purposes, as judged of in this way:—

| | Gallons per head of population daily. |
|---|---|
| New River Company in London 1866,[*] | 23 |
| East London Water-Work Company, „ | 22 |
| Chelsea „ „ | 33·8 |
| West Middlesex „ „ | 30 |
| Grand Junction „ „ | 34 |
| Southwark and Vauxhall „ „ | 21 |
| Lambeth „ „ | 34 |
| Southampton, „ „ | 35 |
| Glasgow, „ „ | 50 |
| Derby,[†] | 14 |
| Nottingham,[†] | 17 |
| Norwich,[†] | 12 |
| Edinburgh, | 35 |
| Liverpool, | 30 |
| Sheffield | 20 |
| Paris, | 31 |
| Calcutta (for European) | 30 |
| „ (for Natives) | 15 |
| New York | 300 |

In 1857 the average suppply to fourteen English towns, of second-rate magnitude, was 24 gallons. The average of 72 English and Scotch towns, supplied on the constant system, is 134·4 gallons per house, (but this includes the supply to factories, of which there were 16,087 to 889,028 houses), or (at 5 persons to each house), 26·7 per head; of 23 towns, supplied on the intermittent system, 127 per house, or 25·4 per head, including 1367 factories to 137,414 houses; and of London, also on the intermittent system, 204, or 41 per head, including 5340 factories to 499,582 houses. (Sixth Report of the Rivers Pollution Commissioners, pp. 232, 233.) The range in individual cases is, however, very great, from 20 gallons per house (4 per head) at Heywood, to 700 at

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[*] These and other London amounts are taken from the Report of the Committee of the House of Commons on the East London Water Bills, 1867, p. 317. The Edinburgh amount is taken from the same work.

[†] From Mr Beggs' pamphlet on "Constant Water Supply," issued by the Social Science Association.

Middlesborough (140 per head). Mr Bateman states that in the manufacturing towns of Lancashire and Yorkshire, the present amount is from 16 to 21 gallons; in some cases less, according to the table in the Sixth Report of the Rivers Pollution Commissioners.

At Norwich about 14½ gallons daily per head are supplied on the constant system, of which 10·5 are taken for domestic purposes, 3 for trade, and ·7 gallons for public and sanitary purposes.* In Manchester the supply is also constant, and is 14 gallons per head for domestic, and 7 for trade purposes.

By a recent decision of the Secretary of State for war, a soldier is to receive 15 gallons daily; no extra allowance is made for the wives and children in a regiment.

The gross amount thus taken is used for different purposes, which must be now considered.

### *Amount for Domestic Purposes, excluding Water-Closets.*

This item includes drinking, cooking, washing the person, the clothes, the house utensils, and the house.

An adult requires daily about 70 to 100 ounces (3½ to 5 pints) of water for nutrition; but about 20 to 30 ounces of this are contained in the bread, meat, &c., of his food, and the remainder is taken in some form of liquid. There are, however, wide ranges from the average. Women drink rather less than men; children drink, of course, absolutely less, but more in proportion to their bulk than adults. The rules for transport vessels allow 8 pints in, and 6 out of the tropics for cooking and drinking. During hot weather and great exertion a man will, of course, drink much more.

In some experiments made for the War Office in 1866, at the Richmond Barracks in Dublin and the Anglesey Barracks in Portsmouth, the amount of the different items of the domestic supply (excluding latrines, which take 5 gallons per head) is thus given:—

| | Gallons per soldier daily. |
|---|---|
| Cook-house, | 1 |
| Ablution rooms and baths, | 4 |
| Cleaning barracks, | 2·25 |
| Wash-house and married people, | 2·5 |
| | 9·75 |

I have measured the water used in several cases; the following was the amount used by a man in the middle class, who may be taken as a fair type of a cleanly man belonging to a fairly clean household:—

| | Gallons daily per one person. |
|---|---|
| Cooking, | ·75 |
| Fluids as drink (water, tea, coffee), | ·33 |
| Ablution, including a daily sponge-bath, which took 2½ to 3 gallons, | 5 |
| Share of utensil and house-washing, | 3 |
| Share of clothes (laundry) washing estimated, | 3 |
| | 12 |

These results are tolerably accordant with the Dublin experiments, if we remember that with a large household there is economy of water in washing utensils and clothes, and that the number of wives and children in a regiment is not great. In poor families, who draw water from wells, I have found the amount to vary from 2 to 4 gallons per head, but then there was certainly not perfect cleanliness.

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* Report by Mr Pole.

Mr Bateman* states that in a group of cottages with 82 inmates, the daily average amount was 7½ gallons per head, and in another group 5 gallons per head. Dr Letheby found in the poor houses in the city of London the amount to be 5 gallons.† In experiments in model lodging-houses, Mr Muir states that 7 gallons daily were used.‡ Mr Easton, in his own house in London, found he used about 12 gallons per head, of which about 5 were for closets, leaving 7 for other uses; but I infer that the laundry washing was not included. In the convict prison at Portsmouth, where there are water-closets, and each prisoner has a general bath once a week, the amount is 11 gallons (Wilson).

In several of the instances just referred to, it may be questioned whether the amount of cleanliness was equal to what would be expected in the higher ranks. In most instances quoted no general baths were used; but it is now becoming so common in England to have bath-rooms, that it is said they are often put even in eight-roomed houses. A general bath for an adult requires, with the smallest adult bath (*i.e.*, only 4 feet long and 1 foot 9 inches wide), 38 gallons, and many baths will contain 50 to 60 gallons. A good shower-bath will deliver 3 to 6 gallons. General baths used only once a-week will add 5 or 6 gallons per head to the daily consumption.

I believe we may safely estimate that for personal and domestic use, without baths, 12 gallons per head daily should be given as a usual minimum supply; and with baths and perfect cleanliness, 16 gallons should be allowed. This makes no allowance for water-closets or for unavoidable waste. If from want of supply the amount of water must be limited, 4 gallons daily per head for adults is probably the least amount which ought to be used, and in this case there could not be daily washing of the whole body, and there must be insufficient change of under-clothing.

If public baths are used the amount must be greatly increased. The largest baths the world has seen (those of Ancient Rome) demanded a supply of water so great as, according to Leslie's calculations, to raise the daily average per head to at least 300 gallons.

### *Amount for Water-Closets.*

The common arrangements with cisterns allow any quantity of water to be poured down, and many engineers consider that the chief waste of water is owing to water-closets. In some districts, by attention to this point, the consumption has been greatly reduced; in one case from 30 to 18, and in another from 20 to 12 gallons per head. It has not yet been precisely determined what quantity should be allowed for water-closets. Small cisterns, termed water-waste preventers, are usually put up in towns with constant water supply, which give only a certain limited amount each time the closet is used. The smallest water-waste preventer holds ⅔ gallon, but this is too little. The better kinds hold 1 to 2 gallons; but even 2 gallons are often insufficient to keep the pan and soil-pipe perfectly clean; the water-waste preventer must be sometimes allowed to fill again, and be again emptied. Considering also that some persons will use the closet twice daily and sometimes oftener, and that occasionally more water must be used for thoroughly flushing the pan and soil-pipe, 6 gallons a-day per head should probably be allowed for closets. In this particular instance a false economy in the use of water is most undesirable. Water latrines require less; the amount is not precisely known; the experiments of the Royal Engineers at Dublin give an average of 5 gallons per head, but it is considered this might be reduced.

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* On "Constant Water Supply," By Messrs Bateman, Beggs, & Rendle. 1867.

† Report of the East London Water Bill Committee, 1867. Questions 2346 and 2347.

‡ Ibid., p. 5.

In fixing the above quantities, viz., 12 gallons per head for all domestic purposes except general baths and closets, 4 gallons additional for general baths, and 6 for water-closets, I shall be considered by some to have fixed the daily supply too high, while by others I shall be accused of the contrary fault. I have endeavoured to base it on facts, and do not think I am much in error. It is, however, necessary to make some allowance for unavoidable waste, and for extra supply to closets, and it will be a moderate estimate to allow 3 gallons daily per head for this purpose. This will make 25 gallons.

There is another reason for believing that an amount of about 25 gallons per head should pass from every house daily into sewers, if sewers are used. It is that in most cases this quantity seems necessary to keep the sewers perfectly clear, though in some cases, no doubt, with a well-arranged and constructed sewerage, a less amount may suffice. But the complete clearage of sewers is a matter of such fundamental importance that it is necessary to take the safest course.

### *Amount for Animals.*

From experiments conducted in some cavalry stables in 1866, by the Royal Engineers, the War Office authorities have fixed the daily supply for cavalry horses at 8 gallons, and for artillery horses at 10 gallons per horse. This is to include washing horses and carriages. The amount seems rather small. Of course the amount that horses drink varies as much as in the case of men, and depends on food, weather, and exertion; but if a horse is allowed free access to water at all times, and this should be the case, he will drink on an average 6 to 10 gallons, and at times more. In the month of October, with cool weather, I found a horse 16 hands high, doing 8 miles a-day carriage-work, and fed on corn and hay, drank 7½ gallons. Another carriage horse drank nearly the same amount. In a stable of cavalry horses, doing very little work, and at a cool time of the year, I found the amount per horse to be 6¼ gallons. The amount used for washing was 3 gallons daily. In hot and dirty weather the quantity for both purposes would be larger. For washing a horse requires at least 1½ gallon, and twice this amount if he is washed twice a-day. There is a saving, however, if grooms wash several horses in the same water. It is difficult to say how much is used for carriage-washing. On the whole, including carriage washing, &c., 16 gallons per horse is not an excessive amount. A cow or an ox, on dry food, will drink 6 or 8 gallons; a sheep or pig, ½ to 1 gallon. In the Abyssinian expedition, the following was the calculation for the daily expenditure of water per head on ship-board:—

| | |
|---|---|
| Elephants, | 25 gallons. |
| Camels, | 10 „ |
| Oxen (large draught), | 6 „ |
| Oxen (small pack animals), | 5 „ |
| Horses, | 6 „ |
| Mules and ponies | 5 „ |

For 20 elephants and 100 men, 50,000 gallons were put on board for a voyage of 60 days.*

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* This information was derived from Major Holland, Assistant Quartermaster-General, Abyssinian Army.

### *Amounts required for Municipal and Trade Purposes.*

For municipal purposes water is taken for washing and watering streets, for fountains, for extinguishing fires, &c. The amount for these and for trade purposes will vary greatly. Professor Rankine,[*] who gives an average allowance of 10 gallons per head for domestic purposes, proposes 10 more for trade and town use in non-manufacturing towns, and another 10 gallons in manufacturing towns. Considering, however, the comparatively small number of horses and cows in towns as compared with the human population, and the frequent rains in this country which lessen watering of streets, these quantities might, perhaps, in most cases be halved.

If, now, the total daily amount for all purposes be stated per head of population, it will be as follows:—

| | Gallons. |
|---|---|
| Domestic supply (without baths or closets), . . | 12 |
| Add for general baths . . . . . . | 4 |
| Water-closets, . . . . . . | 6 |
| Unavoidable Waste, . . . . . . | 3 |
| Total house supply, . . . . . . | 25 |
| Town and trade purposes, animals in non-manufacturing town, | 5[†] |
| Add for exceptional manufacturing towns, . . . | 5 |
| | 35 |

In India and hot countries generally, the amounts now laid down would have to be altered. Much more must be allowed for bathing and for washing generally, while a fresh demand would arise for water to cool mats, punkahs, or air-passages by evaporation. In Calcutta it is intended to supply to Europeans 30 gallons per head, and to natives 15 gallons daily.[‡]

In Madras, it appears to be assumed that the ultimate amount used will be 20 gallons per head, including all residents.[§]

## 2. AMOUNT REQUIRED FOR SICK MEN.

In hospitals a much larger quantity must be provided, as there is so much more washing and bathing. From 40 to 50 gallons per head are often used. I know of no good experiments as to the items of the consumption, but I think the following is near the truth:—

| | Gallons daily. |
|---|---|
| For drinking and cooking, washing kitchen and utensils, . . . . . | 2 to 4 |
| For personal washing and general baths, . . | 18 to 20 |
| For laundry washing, . . . . . | 5 to 6 |
| Washing hospital, utensils, &c., . . | 3 to 6 |
| Water-closets, . . . . . . | 10 |
| | 38 to 46 |

It would be very desirable to have more precise data; possibly the amount for closets is put too high, but not greatly so when all cases are taken into account.

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[*] Civil Engineering, 1862, p. 731.

[†] This allowance will vary in every case, and must be very uncertain.

[‡] Gordon's Army Hygiene, p. 426.

[§] Report by Captain Tulloch on the Drainage of Madras, 1865, p. 93.

## SUB-SECTION II.—COLLECTION, STORAGE, AND DISTRIBUTION OF WATER.

The daily necessary quantity of water per head being determined, the next points are to collect, store, and distribute it.

### 1. COLLECTION.

In many cases collections of water occur naturally in the depressions of the surface, or the commingling of small streams forms rivers. The collection by men consists almost entirely in imitating these natural processes, and in directing to, and finally arresting at some point, the rain or the streamlets formed by the rain. The arrangements necessarily differ in each case. Rain-water is collected from roofs, or occasionally from pavements and flags, or cemented ground; in hilly countries, with deep ravines, a reservoir is sometimes formed by carrying a wall across a valley, which is well placed for receiving the tributary waters of the adjacent hills, or on a flatter surface trenches may be arranged, leading finally to an excavated tank.

The collection of the surface water which has not penetrated is usually aimed at, but it has been proposed by Mr Bailey-Denton* to collect the subsoil water by drainage pipes, and thus to accomplish two objects—to dry the land, and to use the water taken out of it. Below the surface the water is collected by wells, shallow, deep, and Artesian, or by boring.

With respect to wells, if they are situated near a river, and do not produce sufficient water, it has been recommended to lay perforated earthenware pipes parallel to the river, and below its fine-weather level, in trenches not less than 6 feet deep, and filled up above the pipes with fine gravel. The pipes end in the well, and water passing from the river and filtered through the gravel passes into them. The American tube-well (Norton's patent) is a very useful invention. It is merely a small iron pipe driven into the ground in lengths by means of a "monkey;" the water passes through small holes in the lowest part of the pipe, and is drawn up by a common or double action pump according to the depth.†

All these matters fall within the province of the engineer, and the medical part of the question is chiefly restricted to the consideration of the purity of the water. The cleanliness and nature of the surface (lead, zinc, copper, &c.) on which rain falls; the kind of ground; and of cultivation; the amount of manuring; the nature of the subsoil if drainage water is used, and points of the like kind, have to be considered and supplemented by a chemical examination.

*Rain.*—The *amount* of water given by rain can be easily calculated, if two points are known—viz., the amount of rainfall, and the area of the receiving surface. The rainfall can only be determined by a rain-gauge (the mode of constructing which is given in the chapter on PRACTICAL METEOROLOGY); the area of the receiving surface must be measured.

Supposing that it be known that the rainfall amounts to 24 inches per annum, and the area of the receiving surface (say the roof of a house) is 500 square feet;

Multiply the area by 144 (number of square inches in 1 square foot), to bring it into square inches, and multiply this by the rainfall. The product gives the number of cubic inches of rain which fall on the house-top in a year, or in any time the rainfall of which is known. This number, if divided by 277·274, or multiplied by ·003607, will give the number of gallons which the roof of the house will receive in a year (viz., in this case 6232 gallons); or, if it is wished to express it in cubic feet, the number of cubic inches must be divided by 1728 (number of cubic inches in a cubic foot), or multiplied by ·00058.

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* On the Supply of Water to Villages and Farms, by Mr Bailey-Denton, C.E.

† In the Ashantee Expedition the tube well did not succeed, as it got clogged with sand. (See Sir A. D. Home's Report, Army Medical Reports, vol. xv. p. 247).

To calculate the receiving surface of the roof of a house, we must not take into account the slope of the roof, but merely ascertain the area of the flat space actually covered by the roof. The joint areas of the ground-floor rooms will be something less than the area of the roof, which also covers the thickness of the walls and the eaves.

In most English towns the amount of roof space for each person cannot be estimated higher than 60 square feet; and in some poor districts is much less. Taking the rainfall in all England at 30 inches, and assuming that all is saved, and that there is no loss from evaporation, the receiving surface for each person would give 935 gallons, or 2½ gallons a-day. But as few town houses have any reservoirs, this quantity runs in great part to waste in urban districts. In the country it is an important source of supply, being stored in cisterns or water-butts. If, instead of the roof of a house, the receiving surface be a piece of land, the amount may be calculated in the same way.* It must be understood, however, that this is the total amount reaching the ground; all of this will not be available; some will sink into the ground, and some will evaporate; the quantity lost in this way will vary with the soil and the season from one-half to seven-eighths. To facilitate these calculations, tables have been constructed by engineers.†

One inch of rain delivers 4·673 gallons on every square yard, or 22,617 gallons (101 tons by weight) on each square acre.‡

In estimating the annual yield of water from rainfall, and the yield at any one time, we ought to know the greatest annual rainfall, the least, the average, the period of the year when it falls, and the length of the rainless season. It must also be remembered that the amount of rainfall differs very greatly even in places near together.

*Springs, Rivers.*—It will often be a matter of great importance to determine the yield of springs and small rivers, as a body of men may have to be placed for some time in a particular spot, and no engineering opinion, perhaps, can be obtained.

A spring is measured most easily, by receiving the water into a vessel of known capacity, and timing the rate of filling. The spring should be opened up if necessary, and the vessel should be of large size. The vessel may be measured either by filling it first by means of a known (pint or gallon) measure, or by gauging it. If it be round or square, its capacity can be at once known by measuring it, and using the rules laid down in the chapter for measuring the cubic amount of air in rooms. The capacity of the vessel in cubic feet may be brought into gallons if desirable, by multiplying by 6·23. If a tub or cask only be procurable, and if there is no pint or gallon measure at hand, the following rule may be useful:—

Take the bung diameter in inches, by measuring the circumference at the bung, dividing by 3·1416, and making an allowance for the thickness of the staves; square the bung diameter, and multiply by 39. Take the head diameter by direct measurement, and square it, and multiply by 25. Multiply one diameter by the other, and the product by 26. Add the sums, and multiply by the length of the cask; then multiply by ·000031473, and the result is given in gallons.*

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* 9 square feet = 1 square yard.
4840 square yards = 1 square acre.
640 square acres = 1 square mile.
Square yards × ·0002067 = acres.
Lineal feet × ·00019 = miles.

† Beardmore's Manual of Hydrology, p. 61.

‡ To bring cubic inches into gallons, multiply by 40 and divide by 11,091, or multiply at once by ·003607.

When it is required to ascertain the yield of any small water-course with some nicety, it is the practice of engineers to dam up the whole stream, and convey the water by some artificial channel of known dimensions.

1. A wooden trough of a certain length, in which the depth of water and the time which a float takes to pass from one end to the other is measured.

2. A sluice of known size, in which the difference of level of the water above and below the sluice is measured.†

3. A weir formed by a plank set on edge, over which the water flows in a thin sheet, and the difference of level is measured between the top of the plank and the surface of the still water above. Then by means of a table the amount of water delivered per minute is read off. The weir must be formed of very thin board and be perfectly level; a plumb-line has generally to be used.‡

The same object may, however, be attained with sufficient accuracy for the purposes of the medical officer by selecting a portion of the stream where the channel is pretty uniform, for the length of, say not less than 12 or 15 yards, and in the course of which there are no eddies. Take the breadth and the average depth in three or four places, to obtain the sectional area. Then, dropping in a chip of wood, or other light object, notice how long it takes to float a certain distance over the portion of channel chosen. From this can be got the surface velocity per second, which is greater of course than the bottom or the mean velocity. Take four-fifths of the surface velocity (being nearly the proportion of mean to surface velocity), and multiply by the sectional area. The result will be the yield of the stream per second.

It may sometimes be worth while, if labour be at hand, to remove some of the irregularities of the channel, or even to dig a new one across the neck of a bend in the course of the stream.

The yield of a spring or small river should be determined several times, and at different periods of the day.

*Wells.*—The yield of wells can only be known by pumping out the water as far as can be done, and noticing the length of time required for refilling. In cases of copious flow of water, a steam-engine is necessary to make any impression; but, in other cases, pumping by hand or horse labour may be

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* Nesbit's Practical Mensuration, 1859, p. 309. Another rule, applicable to common forms of casks is to multiply the cube of the diagonal by 0·00225; the cube of the diagonal is got by adding the square of half the sum of the diameters to the square of half the length;—then this sum multiplied by its square root gives the cube of the diagonal. This and many other useful calculations can be very conveniently done by means of the common, or carpenter's, slide-rule.

† *Discharge of water through a sluice.*—Multiply breadth of opening by the height; this gives the area of the sluice.

*Discharge=area, multiplied by five times the square root of head of water in feet.*—The head of water is the difference of level of the water above and below the dam, if the sluice be entirely under the lower level; or the height of the upper level above the centre of the opening, if the sluice be above the lower level.

‡ *Discharge of water over a weir* 1 *foot in length.*—If the weir is more or less than a foot, multiply the quantity in the table opposite the given depth by the length of the weir in feet, or decimals of a foot.

| Depth falling over, inches. | Discharge per minute. | Depth falling over, inches. | Discharge per minute. |
|---|---|---|---|
| ½ | 1·70 cubic feet. | 2½ | 19·70 cubic feet. |
| 1 | 4·82 " " | 3 | 26·62 " " |
| 1½ | 8·84 " " | 3½ | 33·22 " " |
| 2 | 13·63 " " | 4 | 40·71 " " |

Thus, if the weir measure 1 foot, and the depth of water falling over be 2 inches, the delivery is read at once, viz., 13·63 cubic feet, or 84·9 gallons per minute.

sufficient perceptibly to depress the water, and then, if the quantity taken ou be measured, and the time taken for refilling the well be noted, an approximate *estimate can be formed of the yield.*

*Permanence of Supply.—It is obvious that the permanence of the supply of a spring or small stream may often be of the greatest moment in the case of an encampment, or in the establishment of a permanent station.*

In the first place, evidence should, when available, be obtained. If no evidence can be got, and if the amount and period of rain be not known, it is almost impossible to arrive at any safe conclusion. The country which forms the gathering ground for the springs or rivers should be considered. If there be an extensive background of hills, the springs towards the foot of the hills will probably be permanent. In a flat country the permanency is doubtful, unless there be some evidence from the temperature of the spring that the water comes from some depth. In limestone regions springs are often fed from subterranean reservoirs, caused by the gradual solution of the rocks by the water charged with carbonic acid; and such springs are very permanent. In the chalk districts there are few springs or streams, on account of the porosity of the soil, unless at the point the level be considerably below that of the country generally. The same may be said of the sandstone formations, both old and new; but deep wells in the sandstone often yield largely, as the permeable rocks form a vast reservoir. In the granitic and trap districts, small streams are liable to great variations, unless fed from lakes; springs are more permanent when they exist, being perhaps fed from large collections or lochs.

## 2. STORAGE.

The amount of storage required will depend on circumstances, viz., the amount used, and the ease of replenishing. It is, of course, easy to calculate the space required when these conditions are known, in this way:—The number of gallons required daily for the whole population must be divided by 6·23 to bring into cubic feet, and multiplied by the number of days which the storage must last; the product is the necessary size of the reservoir in cubic feet.

Many waters, particularly rain water, must be filtered through sand before they pass into small cisterns, and the filter should be cleaned every three or four months. Fig. 1. is a single filter recommended by the Barrack Commission. *

A double filter can be made by having a second chamber.

Whatever be the size of the reservoir, it should be kept carefully clean, and no possible source of contamination should be permitted. In the large reservoirs for town supply, the water is sometimes rendered impure by floods washing surface refuse into them, or by substances being thrown in. In fact, in some cases, water pure at its source becomes impure in the reservoirs.

Some large cities are still supplied principally by rain water, as Constantinople—where under the houses are enormous cisterns,—Venice, and other places. Gibraltar and Malta are in part supplied in this way.

As far as possible, all reservoirs, tanks, &c., should be covered in and ventilated; in form they should be deep rather than extended, so as to lessen evaporation, and secure coolness. Though they should be periodically and carefully cleaned, it would appear that it is not always wise to disturb water plants which may be growing in them; some plants, as the Protococcus, the Chara, and others, give out a very large amount of oxygen, and thus oxidise and render innocuous the organic matter which may be dissolved in the water or volatilised from the surface.* Dr Chevers mentions that the water of *some tanks which were ordered to be cleared of water plants by Sir Charles Napier, deteriorated in quality. Other plants, however, as some species of duckweed (Lemna at home, Pistia in the tropics), are said to contain an acrid matter which they give off to the water.* It would be well to remove some of the plant, place it in pure water in a glass vessel, and try by experiment whether the amount of organic matter in the water is increased, or whether any taste is given to the water. Dead vegetable matter should never find its way into, or at any rate remain in, the reservoir.

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* Report on the Mediterranean Stations, 1863.

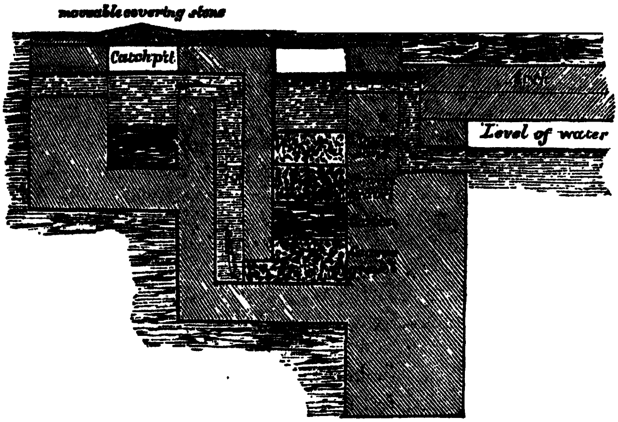

Fig. 1.

Whenever a reservoir is so large that it cannot be covered in, a second smaller covered tank, capable of holding a few days' supply, might be provided, and this might be fitted with a filter, through which the water of the large reservoir might be led as required.

When tanks are large they are made of earth, stones, or masonry; if mortar be used, it should, as in the case of the smaller reservoirs, be hydraulic, so that it may not be acted on by the water.

The materials of small reservoirs and cisterns are stone, cement, brick, slate, tiles, lead, zinc, and iron. Of these slate is the best, but it is rather liable to leakage, and must be set in good cement; common mortar must not be used for stone or cement, as lime is taken up and the water becomes hard. Leaden cisterns, as in the case of leaden pipes, may yield lead to water, and should be used as little as possible, or should be protected. Lead cisterns are often corroded by mud or mortar, even when no lead is dissolved in the water. Iron cisterns and pipes are often rapidly eaten away; they are now sometimes protected by being covered inside with Portland cement or with a vitreous glaze. Crease's patent cement is a very useful covering. Perhaps Barff's process of producing the magnetic oxide on the surface of iron may be utilised. Iron tanks are now very much used. They must be covered, and in India be protected from the sun. Zinc has been said to be a good material; water acts a little upon it, but generally the compounds formed (hydrated oxide, zinc ulmate†) are almost insoluble. Nevertheless, it is said that water passing through zinc pipes, or kept in zinc pails, may produce symptoms of metallic poisoning.*

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* Clemens in Archiv. für Physiol. Heilk. 1853.
† Fonssagrives, Ann. d'Hyg. Jan. 1864. p. 857.

Cisterns should always be well covered, and protected as much as possible from both heat and light. Care should always be taken that there is no chance of leakage of pipes into them. A common source of contamination is an overflow pipe passing direct into a sewer, so that the sewer gases pass up, and being confined by the cover of the cistern, are absorbed by the water; to prevent this, the overflow pipe is curved so as to retain a little water and form a trap, but the water often evaporates, or the gases force their way through it; *no overflow pipe should therefore open into a sewer, but should end above ground over a trapped grating.† A cistern supplying a water-closet should not be used to supply cooking and drinking water, as the pipes leading to the closet often conduct closet air to the cistern. Hence, a small cistern (water waste preventer) should be used for each closet. Cisterns should be periodically* and carefully inspected; and in every new building, if they are placed at the top of the house, convenient means of access should be provided.

Tanks to hold rain-water require constant inspection.

Wells (which are really reservoirs) are very liable to contamination from surface washings during rains. A good coping will often prevent this; but if there is much subsoil soaking, lining with iron to a certain depth, or covering with brickwork set in cement for a sufficient depth, to arrest the flow, may be desirable.

### 3. Distribution.

When houses are removed from sources of water the supply should be by aqueducts and pipes. The distribution by hand is rude and objectionable, for it is impossble to supply the proper quantity, and the risks of contamination are increased. Some of the most extraordinary of the Roman works in both the Eastern and Western Empires were undertaken for the supply of water—works whose ruins excite the astonishment and should rouse the emulation of modern nations.

The plans for the distribution of water should include arrangements for the easy and immediate removal of dirty water. This is an essential point, for in many towns where houses are not properly arranged for small families, there are no means of getting rid of water from the upper rooms, and this inconvenience actually limits the use of water, even when its supply is ample.

The supply of water to houses may be on one of two systems, intermittent or constant. The difference between the two plans is, that in the first case there is storage in the houses for from one to three days; while in the latter case, there is either no storage, or it is only on a very small scale for two purposes, viz., for water-closets and for the supply of kitchen boilers.‡ It should, however, be understood that the constant supply does not mean an unlimited supply, nor is it the fact that the water in the house pipes is always in direct communication with the water in the reservoirs. On the contrary, the water to the houses is often cut off, particularly in places where the supply is limited, and fittings are not good, and there is great waste.

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* My friend, Dr Orsborn, of Bitterne, has seen several cases of this kind. [In some cases, at least, water left in the so-called galvanized vessels for any length of time,—a good many days,—tastes strongly of zinc salts.—F. de C.]

† For an instance of Typhoid fever produced by this cause, see Lectures on State Medicine, by F. de Chaumont, p. 76, 77.

‡ Much valuable evidence on the constant supply may be found in the Report of the House of Commons Committee on the East London Water Bills, 1867. It is curious to see how difficult the definition of a constant supply was found to he. The difference of opinion between engineers on the desirability of a constant supply is shown to be considerable. The statements in the text are drawn from a collation of this evidence, and from a consideration of Mr Bateman's pamphlet, and many other works.

The great arguments against storage on the premises (except on a limited scale for closets and boilers) are the chances of contamination in cisterns, and the very imperfect means of storage. In poor houses wooden casks or barrels are often used, and may be placed in the worst situations. The arguments against the storage system are certainly directed in part against removable failures. If every house had a good cistern in a proper place, *i.e.*, secured from contamination, and capable of easy inspection and cleansing; if, in fact, the details of the system were good, it might be argued that storage on the premises would be the best plan, as giving without fail, and at all times of day and night, a sufficient supply of water, not merely for common use, but *for emergencies. It must, however, be admitted that,* especially *in poor houses, the inspection and cleansing even of a well-placed cistern will never be properly done, and that with all precautions the chances of contamination of the water during storage are very great. As regards this point, the constant system has a very great superiority, for there is no chance of contamination* except in the reservoir or in the pipes. So great an advantage is this in a sanitary point of view, that almost all those who have paid most attention to sanitary affairs have advocated the constant system. It is, however, quite necessary that it should be understood what the constant system sometimes is in practice. When there is an abundance of water, as at Glasgow, the stoppages of water may be few, but when water has to be economised, the water is from time to time shut off from the house pipes, and then no water may be procurable for hours. This, however, is avoided as much as possible in the day time, so that the inconvenience is reduced to a minimum. In some cases, again, in order to economise water, a throttle or ferule is introduced into the communication or house pipe,* lessening the diameter to $\frac{1}{8}$th or even to $\frac{1}{16}$th of an inch, or smaller, so that if the head of pressure be small the water flows very slowly, and sometimes merely dribbles. In other cases, a meter is put on a pipe communicating with several houses; and the owner of the houses is charged for the water, and this leads him to enforce a very sparing use of it. In all these ways the constant system may tell against the consumer; while, on the other hand, great waste, leaking fittings, and fraudulent abstraction of water (to avoid which there are several ingenious contrivances) tell against the company, and lead to a depreciation of their property. Another injury is also sometimes inflicted on the company, for their fittings are stolen, and besides the loss, an enormous waste of water may be caused, and not be detected for some time.

In spite of all these difficulties, the system of constant supply, in some shape or other, has been carried out in about 150 towns in England; † and the Metropolis Water Act of 1871 has now ordered constant supply for London, if demanded by the rate-payers, and if proper fittings are provided.

In providing a constant supply, certain precautions are necessary. The fittings must be as perfect as possible. In some cases, when the system has been changed from the intermittent to the constant system, as in Chester, the waste of water has been so great that the old plan has been recurred to. Common taps do not answer, and the best screw taps and fittings must be used. ‡ To prevent theft, it has been proposed to make the removal of fittings a specific offence, punished summarily by imprisonment, and to place the *sale of such property under the same restrictions as in the case of Crown property.*

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* The terms used to describe the pipes differ a little apparently; the mains and district or sub-mains are the large pipes, which are always full of water, the latter being of course the smaller; the service-pipe is another term for a district main. The communication-pipe is that which runs from the service-pipe to the house, and in the house it takes the name of house-pipe.

† Mr Beggs' Pamphlet, *op. cit.* page 20.

‡ A bad ball-cock has been known to drop 12 gallons a day.

One important *sanitary advantage of the constant system is that, in order* to facilitate inspection and detection of waste, no waste pipe is allowed to open into a sewer, but it is always so placed that any escape of water can be easily seen (the so-called warning pipe). The great evil of sewer gases being conducted back into houses through overflow pipes is thus avoided. Careful inspection and good fittings so far lessen the waste of the constant system, that in some cases less water is used than under the intermittent plan.*

Some engineers have proposed what may be called a compromise between the intermittent and constant systems. They would allot to a house of a certain size and population a given daily amount of water, and give an equal storage, with a cistern, and would then deliver through a tube with a very small orifice an amount of water in twenty-four hours just equal to the storage. In that way the day would commence with the storage of the night, which would be sufficient for the morning washing. The water company could not lose in this way; and it would be for the tenant to look after his fittings if at any time he found himself without water. The objection to this plan is that cisterns are reintroduced, and their lessened size does not remove the objections to them.

If the constant system is used, a good screw stop-cock, available to the tenant, should be placed at the point of the entrance of the pipe into the house, so that the water may be turned off if pipes burst, or to allow the pipes to be empty, as during frost. Every precaution must be taken that impure water is not drawn into the pipes by a pipe being emptied and sucking up water from a distance.†

For the supply of a very large city, it might be desirable to divide the city into sections, and to establish a reservoir for each district, holding three or four days' supply. In this way the waste of one section would not take away the water from another. In some instances, people in one part of a town supplied with the constant system, have used so much water for gardens that other parts have been altogether deprived of supply. The system of secondary reservoirs would not only lessen this chance, but would make it possible to ascertain that every part of the town was getting its supply. The number of have a great protective power), and, in a less degree, calcium sulphate; and, perhaps, in a still less degree, magnesian salts, and the alkaline phosphates;[*] but it has been said that perfectly pure water, containing no gases, has no action on lead. The deposit which frequently coats the lead consists of carbonate, phosphate, and sulphate, of lead, calcium, and magnesium, if the water have contained these salts, and lead chloride.[†]

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* Evidence of Mr Easton in the Report of Committee on the East London Water Bills, 1867.

† The Board of Trade issued a Minute in 1872 laying down regulations and defining the kind of fittings and arrangements for London; the following are the principal points: lead pipes to be of certain strength (if internal diameter is ⅜ in., ½ in., ⅝ in., ¾ in., 1 in., 1¼ in., the respective weights per lineal yard are to be 5 lb., 6 lb., 7½ lb., 9 lb., 12 lb., 16 lb.). Every pipe in contact with the ground to be of lead; each house to have a communication pipe, but only one, unless an owner has it for a block of houses; connection of every communication pipe to be by a brass screwed ferule or stop-cock with a clear area of water way equal to ½ inch, every joint to be a "plumbing" or "wipe" joint. No pipe to pass through an ash-pit, manure heap, drain, unless it cannot be avoided, and then the pipe is to be laid in an exterior cast-iron pipe or jacket; each pipe in the ground to be 30 inches below surface; each communication pipe to have near the entrance into the house a screwdown stop-valve; if in the ground such valve to be protected by proper cover and guard box; every cistern to be water-tight, to have a good "ball-tap;" no waste-pipe except a "warning pipe," and such warning pipe to be so placed as to be easily inspected. No cistern buried in ground to be used; wooden cisterns to have metallic linings; every water-closet, urinal, or boiler shall be served only from a cistern, and shall not be in direct communication with the water-pipes; closets and urinals to have water-waste preventers; every "down pipe" into a water-closet to have an internal diameter of not less than 1¼ inch, and to weigh not less than 9 lb, per lineal yard. No bath to have an overflow pipe except of the "warning" kind; the outlet must be distinct from the inlet, and the inlet shall be higher than the highest stand of the water. Lead warning pipes, of which the ends are open, and which cannot remain charged with water, may have the following minimum weight; ½ inch diameter to have a weight 3 lbs. per yard; ¾ in., 5 lbs.; 1 in., 7 lb

3. From the observations of Graham, Hofmann, and Miller, the protective influence of carbonic acid gas appears to be very great; a difficultly soluble lead carbonate is formed. However, a very great excess of free carbonic acid may dissolve this. This has perhaps led to the statement that carbonic acid counteracts the preservative effects of the salts.[‡] Water charged with carbonic acid under pressure has a very marked solvent action on lead (Pattison Muir).

Other substances may find their way into water, which may act on lead—as vegetable and fatty acids, arising from fruits, vegetables, &c., or sour milk or cider, &c.

4. The lead itself is more easily acted upon if other metals, as iron, zinc, or tin, are in juxta-postition; galvanic action is produced. Bending lead pipes against the grain, and thus exposing the structure of the metal, also increases the risk of solution; zinc pipes, into the composition of which lead often enters, yield lead in large quantities to water, and this has been especially the case with the distilled water on board ships.

### AMOUNT OF DISSOLVED LEAD WHICH WILL PRODUCE SYMPTOMS OF POISONING.

Dr Angus Smith refers to cases of lead paralysis in which as little as $\frac{1}{100}$th of a grain per gallon was in the water. Adams also ("Trans. of the American Medical Society," 1852, p. 163) speaks of $\frac{1}{100}$th of a grain causing poisoning. Graham speaks of $\frac{1}{57}$th of a grain per gallon as being innocuous. Angus Smith says that $\frac{1}{40}$th of a grain per gallon may affect some persons, while $\frac{1}{10}$th of a grain per gallon may be required for others.[§] But it is difficult to prove it may not at some time have been more than this. Calvert found that water which had been decidedly injurious in Manchester contained from $\frac{1}{10}$th to $\frac{3}{10}$ths of a grain per gallon.

In the celebrated case of the poisoning of Louis Philippe's family at Claremont, the amount of lead was $\frac{7}{10}$ths of a grain per gallon; this quantity affected 34 per cent. of those who drank the water.

The water of Edinburgh is said to contain only $\frac{1}{140}$th of a grain per gallon, which is not hurtful.[‖]

On the whole, it seems probable that any quantity over $\frac{1}{20}$th of a grain per gallon should be considered dangerous, and that some persons may even be affected by less quantities.[¶]

### PROTECTION OF LEAD PIPES.

The chief means which have been proposed are:—

(*a*) Lining with tin. Calvert's experiments[**] show that extra tinned and ordinary tinned lead piping both gave up lead to the pure water now used at Manchester.

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[*] Report of the Government Commission, 1851, p. 7.

[†] Lauder Lindsay, Action of Hard Water on Lead, p. 7.

[‡] There is some discrepancy of opinion as to the action of the chlorides.

[§] Wanklyn adopts $\frac{1}{10}$th of a grain per gallon as justifying rejection of a water;—$\frac{1}{20}$th would probably be a safer limit.

[‖] Chemical News, September 28, 1861.

[¶] See also Taylor's Med. Jurisp., 1865, p. 242; and opinions of Penny, ibid. p. 241.

[**] Chemical News, September 28, 1861.

(*b*) A much better plan is by having a good block-tin pipe inclosed in a lead pipe, as in Haines' patent. If the tin is good, it is little acted on, and the strength of the pipe is increased, while bends and junctions can be made without destroying the continuity of the tin.*

(*c*) Fusible metal, viz., lead, bismuth, and tin. This is certainly objectionable.

(*d*) Bituminous coating (M'Dougall's patent). This is said to be effectual, but I am not aware of any exact experiments.

(*e*) Various gums, resins, gutta percha, and india-rubber. These would probably be efficacious, but I am ignorant of any evidence to show how long they will adhere.

(*f*) Coating interior of pipes with lead sulphide by boiling the pipes in sodium sulphide for fifteen minutes. The sodium sulphide may be made by boiling sulphur in liquor sodæ. (Schwartz's patent.)

(*g*) Rosin and grease with white lead (!) has been proposed, also rosin and arsenic. Both are most objectionable.

(*h*) Varnish of coal tar.†

### SUBSTITUTES FOR LEAD PIPES.

Cast and wrought iron pipes can be used, and Mr Rawlinson informs me that he now orders no others. The iron can be glazed internally.‡ Copper tinned and block-tin are also employed, and both are excellent, but are rather expensive. In some cases the tin is eaten through, but this is not common.§ Zinc, which speedily gets covered with an insoluble oxide, can be used, if the water contains calcium carbonate, as this is said to prevent the free carbonic acid from dissolving the oxide. Gutta percha and bituminised paper pipes have been proposed, but at present are not in much, if in any, use. Artificial stone has also been employed.

## SECTION II.

## QUALITY OF DRINKING WATER.

### SUB-SECTION I.—COMPOSITION.

The composition of water is of importance for several economic purposes; for certain trades which require careful processes of washing and dyeing; for the supply of engines, &c. But these subjects are too technical to be discussed here, and I have restricted this chapter to the quality of water as used for drinking purposes. The only domestic matter of importance connected with quality, apart from drinking and cooking, is the relative amount of soap used by hard and soft water in washing. But this is so obvious a matter that it only requires to be alluded to.

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* The composite pipes of this kind made by Messrs Walker, Parker, & Co. are said to withstand any amount of torsion. On the authority of Professor Reynolds (Manual of Health for Ireland) it is said, that lead alloyed with 3 per cent. of tin is not acted upon by water; pipes of this kind appear to be used in Dublin and in Glasgow.

† Lauder Lindsay, Action of Hard Water on Lead, p. 21.

‡ Iron pipes coated inside with Angus Smith's bituminous varnish are a good deal used. In experiments made at Netley these were found to yield a distinct taste of tar to the water for a considerable time; after a time, however, this action ceased. Probably Barff's process of producing a surface of magnetic oxide on iron will come into use.

§ I have seen block tin pipes eaten through by water at Woolston, apparently in consequence of the presence of nitrates. [F. De. C.]

Owing to many of the domestic uses of water, such as the washing of utensils, the supply for closets, &c., not requiring a very pure water, it has been proposed in some cases to supply water from two sources—one pure for drinking and cooking, the other impure. This requires, however, two sets of pipes, and involves the chance of mistake between two waters; and it is only likely to be of use under exceptional circumstances.

Drinking water is supplied from shallow, deep, and Artesian Well sources: rain, rivers, wells, springs, &c.

*Rain Water.*—As it falls through the air, rain becomes highly aerated (average, 25 cubic centimetres per litre), the oxygen being in larger proportion than in atmospheric air (32 per cent., or a little more); carbonic acid constitutes 2½ or 3 per cent. of the gas. It carries down from the air ammoniacal salts (carbonate, nitrite, and nitrate), and nitrous and nitric acids in small amount. The total quantity of nitrogen in ammoniacal salts, nitrous and nitric acid, is ·000985 grammes per litre. In towns with coal-fires it takes up sulphurous and sulphuric acids, and sometimes sulphuretted hydrogen. The sulphates in rain increase, according to Dr Angus Smith,[*] as we pass inland, and before large towns are reached; they are, according to this author, "the measure of the sewage in air" when the sulphur derived from the combustion of coal can be excluded, but in this country the exclusion could never be made. Free acids are not found with certainty, according to Smith, when combustion and manufactures are not the cause. The acidity taken as sulphuric anhydride was equal to ·0097 grains per gallon of rain in a country place in Scotland, and 1·0589 grains in Glasgow; in Manchester in 1870 it was ·8416, and in London, ·2713 grains. The nitric acid in Glasgow was as much as ·1705 grains per gallon, and in London only ·06188. Albuminoid ammonia was no less than ·326 parts in a million in London rain (A. Smith, *op. cit.* p. 363). Rain also carries down many solid substances, as sodium chloride, in sea air; calcium carbonate, sulphate, and phosphate; ferric oxide; carbon. It almost always contains also a little nitrogenous organic matter, amounting in extreme cases to as much as ·35 grains per gallon. The total amount of solids (mean of 5 analyses[†]) is 0·032 grammes per litre, or 2·24 grains per gallon.[‡]

Occasionally microscopic plants of the lowest order (as *Protococcus pluvialis* and others) are present.

Rain also often becomes very impure from taking up substances (lead, zinc, &c.) from the receiving surface on which it falls, and it also often carries down portions of leaves, &c., into the pipes and reservoirs, which slowly dissolve in it.

*With regard to rain as a source of supply.*—The uncertainty of the rainfall from year to year, the length of the dry season in many countries, and the large size of the reservoirs which are then required, are disadvantages. On the other hand, its purity and its great aeration make it both healthy and pleasant. The greatest benefits have resulted in many cases (especially in some of the

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[*] Air and Rain, 1872, p. 245.

[†] Quoted by Moleschott, Phys. der Nahrungsmittel, 2d edit. p. 203.

[‡] In rain-water collected at St Albans, in the middle of an arable field, two feet from the ground, Frankland found as much as 8·58 parts in 100,000, or 6·006 grains per gallon; mean of 63 sample, 3·86 parts per 100,000, or 2·701 gr. per gallon. From the roof of the Land's End Hotel (Cornwall) 42·8 per 100,000, of which one half was chlorides.

In a sample from supply tank in officers' quarters at Portland I found 47·95 gr. per gallon of solids, of which about 10 were chlorides; the organic constituents were also very large. In another sample, gathered as collected, 32·55 total solids and 14 chlorides; and in one from a pipe leading to the cookhouse, 59·25 total solids and 15·2 chlorides. In a sample collected through funnels direct into glass bottles, the solids were 6·65 per gallon, of which 4·9 were volatile, chiefly ammonium chloride, &c. [F. de C.]

West Indian Islands) from the use of rain instead of spring or well water, which is often largely impregnated with earthy salts. In all places where the spring or well water is thus bad, as in the neutral ground at Gibraltar, rain water should be substituted. So also it has been suggested that in outbreaks of cholera anywhere, the rain water is less likely to become contaminated with sewage matters than wells or springs, into which organic matters often find their way in an unaccountable manner.

*Ice and Snow Water.*—In freezing, water becomes much purer, losing a large portion, sometimes the whole, of its saline contents. Even calcium carbonate and sulphate are thus got rid of. The air is at the same time expelled. Ice water is thus tolerably pure, but heavy and non-aerated. Snow water contains the salts of rain water with the exception of rather less ammonia. The amounts of carbonic acid and air are very small.

There has long been an opinion that snow water is unwholesome, but this is based on no reliable observations. In Northern Europe, however, the poorer classes have the habit of taking the snow lying about their dwellings, and as this is often highly impure with substances thrown out from the house, this water may be unwholesome. It has been conjectured that the spread of cholera in the Russian winter in 1832, was owing to the use of such snow water contaminated by excretions.

*Dew* has occasionally been a source of supply to travellers in sterile regions in South Africa and Australia, or on board ship.

*Spring, Well, and River Water.*—The rain falling on the ground partly evaporates, partly runs off, and partly sinks in. The relative amounts vary with configuration and density of the ground, and with the circumstances impeding or favouring evaporation, such as temperature, movement of air, &c. In the magnesian limestone districts, about 20 per cent. penetrates; in the new red sandstone (Triassic), 25 per cent.; in the chalk, 42; in the loose tertiary sand, 90 to 96.

Penetrating into the ground, the water absorbs a large proportion of carbonic acid from the air in the interstices of the soil, which is much richer (250 times) in $CO_2$ than the air above. It then passes more or less deeply into the earth, and dissolves everything it meets with which can be taken up in the time, at the temperature, and by the aid of carbonic acid. In some sandy soils there is a deficiency of $CO_2$, and then the water is also wanting in this gas, and is not fresh and sparkling.

The chemical changes and decompositions which occur in the soil by the action of carbonic acid, and which are probably influenced by diffusion, and perhaps pressure, as well as by temperature, are extremely curious,* but cannot be entered upon here. The most common and simple are the solution of calcium carbonate, and the decomposition of calcium and sodium silicate by carbonic acid, or alkaline carbonates. Salts of ammonia also, when they exist, appear from Dietrich's observations to have a considerable dissolving effect on the silicates.

Fed from a variety of sources, river water is even more complex in its constitution than spring water; it is also more influenced by the season, and by circumstances connected with season, such as the melting of snow or ice, rains and floods, &c. The water taken on opposite sides of the same river has been found to differ slightly in composition.

The general result of solution and decomposition is that the water of springs and rivers often contains a great number of constituents—some in very small, others in great amount. Some waters are so highly charged as to be termed mineral waters, and to be unfit for drinking, except as medicines. The impurities of water are not so much influenced by the depth of the spring as by the strata it passes through. The water of a surface spring, or of the deepest Artesian well, may be pure or impure. The temperature of the water also varies, and is chiefly regulated by the depth. The temperature of shallow springs alters with the season; that of deeper springs is often that of the yearly mean. In very deep springs, or in some Artesian wells, the temperature of the water is high.

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* These are given in detail by G. Bischof, "Chemical and Physical Geology" (Cavendish Society's edit.), 1854, vol. i. p. 2, *et seq.*; and in "Watt's Dictionary of Chemistry;" Article, Chemistry of Geology, by Dr Paul.

The substances which are contained in spring, river, and well waters are noted more fully under the head of "Examination of Water." There may be suspended matters, mineral, vegetable, or animal; dissolved gases, viz., nitrogen, oxygen, carbonic acid, and in some cases sulphuretted hydrogen, and carburetted hydrogen; and dissolved solid matters, consisting of lime, magnesia, soda, potassa, ammonia, iron, alumina, combined with chlorine, and sulphuric, carbonic, phosphoric, nitric, nitrous, and silicic acids. More infrequently, or in special cases, certain metals, as arsenic, manganese, lead, zinc, and copper may be present.

The mode of combination of these substances is yet uncertain; it may be that the acids and bases are equally distributed among each other, or some other modes of combination may be in play. The mode of combination is *usually* assumed to be as follows.* The chemist determines the amount of each separate substance, and then calculates the combination as follows. The chlorine is combined with sodium; if there is an excess, it is combined with potassium or calcium; if there is an excess of soda, it is combined with sulphuric acid, or if still in excess, with carbonic acid. Lime is combined with excess of chlorine, or sulphuric acid, or if there be no sulphuric acid, or an excess of lime, with carbonic acid. Magnesia is combined with carbonic acid. So that the most usual combinations are sodium chloride, sodium sulphate, sodium carbonate, calcium carbonate (held in solution by carbonic acid), calcium sulphate, calcium chloride and silicate, and magnesium carbonate; but the results of the analysis may render other combinations necessary.

*Distilled Water.*—Distillation is now very largely used at sea, and affords an easy way of getting good water from sea or brackish water. Almost any form of apparatus will suffice, if fuel can be procured, to obtain enough water to support life; and if even the simplest appliances are not attainable, the mere suspension of clean woollen clothing over boiling water will enable a large quantity to be collected. At sea, salt water is sometimes mixed with it from the priming of the boilers, and occasionally from decomposition of magnesium chloride (probably), a little free hydrochloric acid passes off. This can, if necessary, be neutralised by sodium carbonate.

As distilled water is nearly free from air, and is therefore unpalatable to some persons, and is supposed indigestible,† it may be aerated by allowing it to run through a cask, the bottom of which is pierced with fine holes, so as to expose the water to the air. Plans for aerating the water distilled from sea water have been proposed by Normandy and others, and are used in many steamers. Organic matter, at first offensive to taste and smell in distilled water, can be got rid of by passing through a charcoal filter, or by keeping three or four days.

Care should be taken that no lead finds its way into the distilled water.

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* Fresenius, Quantitative Analysis, 3rd edit. p. 481.

† By some even dangerous (Gérardin).

Many cases of lead poisoning have occurred on board ships, partly from the use of *minium* in the apparatus, and partly from the use of *zinc pipes* containing lead in their composition.

*Comparative Value of Spring, River, and Well Water as Sources of Supply.*

This depends on many circumstances. Spring water is both pure and impure in different cases; and the mere fact of its being a spring is not, as sometimes imagined, a test of goodness. Frequently, indeed, river water is purer than spring water, especially from the deposit of calcium carbonate; organic matter is, however, generally in greater quantity, as so much more vegetable matter and animal excreta find their way into it. The water of a river may have a very different constitution from that of the springs near its banks. A good example is given by the Ouse, at York; the water of this river is derived chiefly from the millstone grit which feeds the Swale, the Ure, and the Nid, tributaries of the Ouse; the water contains only 9 grains per gallon of salts of calcium, magnesium, sodium, and a little iron. The wells in the neighbourhood pass down into the soft red sandstone (Yoredale series) which lies below the millstone grit; the water contains as much as 64·96 grains, and even, in one case, 96 grains per gallon; in addition to the usual salts, there is much calcium chloride and calcium, sodium, and magnesium nitrates. Shallow well water is always to be viewed with suspicion; it is the natural point to which the drainage of a good deal of surrounding land tends, and heavy rains will often wash many substances into it.* The following table is given by the Rivers Pollution Commissioners (Sixth Report, p. 129):—

| | | |
|---|---|---|
| Wholesome | 1. Spring-water, . . | very palatable. |
| | 2. Deep well-water, . | |
| | 3. Upland surface water | moderately palatable. |
| Suspicious | 4. Stored rain-water, . | |
| | 5. Surface water from cultivated land, . . | palatable. |
| Dangerous | 6. River water, to which sewage gains access, | |
| | 7. Shallow well water, . . . . | |

SUB-SECTION II.—CHARACTERS AND CLASSIFICATION OF DRINKING WATERS.

The general characters of good water are easily enumerated. Perfect clearness; freedom from odour or taste; coolness; good aeration; and a certain degree of softness, so that cooking operations, and especially of vegetables, can be properly performed, are obvious properties. But when we attempt a more complete description, and assign the amounts of the dissolved matters which it is desirable should not be exceeded, we find considerable difference of opinion, and also a real want of evidence on which to base a satisfactory judgment. At the Sanitary Congress held at Brussels in 1853, it was decided that the total solids ought not to exceed 0·5 grammes per litre (= 35 grains per gallon), and the same amount had been previously laid down in the "Annuaire des Eaux de la France pour 1851" (p. 14); but this statement is really of little use, since this quantity of some salts would be hurtful, of others harmless.

Still, an hygienic classification or enumeration of potable waters, based on such facts as are generally admitted, will be useful. I have divided all kinds of waters used for drinking into four classes:—

1. Pure and wholesome water.
2. Usable "
3. Suspicious "
4. Impure "

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* Dr Cameron (Dublin Journal of Medical Science) cites a case where good and bad water were obtained from different levels in the same well.

And the following description will define these terms :—

HYGIENIC CLASSIFICATION OF DRINKING WATERS.

| Character or Constituent. | 1. Pure and Wholesome Water. | 2. Usable Water. | 3. Suspicious Water. | 4. Impure Water. | Remarks. |
|---|---|---|---|---|---|
| Clearness, lustre, and aëration, . . . | Transparent, sparkling, and well aërated. | Transparent, sparkling, and well aërated. | Turbid. | Turbid and not easily purified by coarse filtration. | Turbidity, due to very fine mineral matter, is sometimes associated with pure waters: thus, minutely divided calcium sulphate will not subside in distilled water. |
| Suspended matter, . . . . | None detectable by the eye. | Absent or easily separable by coarse filtration or subsidence. | Considerable. | Large. | |
| Colour, . . . | Colourless. | Colourless or slightly greenish. | Yellowish. | Distinctly yellow or any marked colour. | Where the impurity is mostly vegetable, the colour may be very marked in good, or at least usable water. |
| Taste, . . . . | Palatable. | Palatable. | Any marked taste. | Any marked taste. | |
| Smell, . . . | None. | None. | None. | Any marked odour. | |
| Solids (dissolved) : Total, . | Under 8 grs. per gal. (=114 parts per mil.). | Under 30 grs. per gal. (=428 parts per mil.). | Above 30 grs. per gal. (=428 parts per mil.). | Above 50 grs. per gal. (=714 parts per mil.). | In chalk waters of the 1st class the solids may reach 14 grains per gallon (=200 parts per million), the greater part being calcium carbonate. |
| Solids, volatile (capable of being dissipated by red heat), . . . | Under 1 gr. per gal. (=14 parts per mil.).<br>Solids on incineration should scarcely blacken. | Under 3 grs. per gal. (=43 parts per mil.).<br>Solids may blacken a little, but no fumes should be given off. | 3 to 5 grs. per gal. (=43 to 71 parts per mil.).<br>Much blackening on incineration or nitrous fumes given off. | Above 5 grs. per gal. (=71 parts per mil.).<br>Much blackening and nitrous fumes given off, or smell of burnt horn. | In peat waters the incinerated solids may blacken considerably. |
| Chlorine, . . | Under 1 gr. per gal. (=14 parts per mil.). | Under 3 grs. per gal. (=43 parts per mil.). | Above 3 grs. per gal. (=43 parts per mil.). | Above 6 grs. per gal. (=86 parts per mil.). | Water, slightly contaminated with sea-water, may have a higher amount of chlorine and still be usable. |
| Nitrites, . . . | Absent. | Absent. | Present. | Marked. | These are generally indications of previous animal contamination, but they may occasionally come from vegetable matter. |
| Nitrates, . . . | Absent or very faint trace. | Present. | Marked. | Large. | |
| Oxygen required for oxidisable organic matter, determined by permanganate in presence of acid. | Under 0·07 grs. per gal. (=1 part per mil.). | Under 0·105 grs. per gal. (=1·5 parts per mil.). | Above 0·105 grs. per gal. (=1·5 parts per mil.). | Above 0·14 grs. per gal. (=2·0 parts per mil.). | The amount may be greater in good peat waters. |
| Ammonia: free or saline, . . | Under 0·0014 grs. per gal. (=0·02 parts per mil.). | Under 0·0035 grs. per gal. (=0·05 parts per mil.). | Above 0·0035 grs. per gal. (=0·05 parts per mil.). | Above 0·0070 grs. per gal. (=0·10 parts per mil.). | Frankland's standard for good water is: 2 to 2 parts per million of organic carbon; 0·2 parts per million of organic nitrogen. He also gauges it by the "previous sewage contamination," as measured by the nitrogen existing as nitrates—about 1 part per million being the limit of inorganic nitrogen in "reasonably safe" waters. |
| Ammonia: albuminoid or organic, . . . | Under 0·0056 grs. per gal. (=0·08 parts per mil.). | Under 0·0070 grs. per gal. (=0·10 parts per mil.). | Above 0·0070 grs. per gal. (=0·10 parts per mil.). | Above 0·0105 grs. per gal (=0·15 parts per mil.). | |
| Hardness, fixed, | 2° Clark's scale. | Under 4° Clark's scale. | Above 4° Clark's scale. | Above 6° Clark's scale. | |
| Metallic contamination, . | None. | Trace of iron. | Trace of iron. | Any metal except iron. | |
| Hydrogen or alkaline sulphides, . . . | Absent. | Absent. | Absent. | Present. | |
| Microscopic characters, . . | Mineral matter: vegetable forms with endochrome; large animal forms; no organic debris. | Same as No. 1. | Vegetable and animal forms more or less pale and colourless: organic debris; fibres of clothing, or other evidence of house refuse. | Bacteria of any kind: Fungi; numerous vegetable and animal forms of low types; Epithelia or other animal structures; evidences of sewage; ova of parasites, &c. | N.B.—Frankland's numbers are stated per 100,000, instead of per million. (See "Rivers' Pollution Commissioners' Sixth Report," page 13 and *seq.*). |

*N.B.*—"Parts per mil." mean "Parts per million," equal to "milligrammes per litre."

It must, of course, be understood that it is not necessary that *all* the above characters should be present in one water to place it in a particular class; nor would it be right to condemn a water for one character alone. Thus, although any marked deviation from the above conditions might be sufficient to remove a water from class 1, it would scarcely be fair to degrade a water further on account of its mineral characters only. On the other hand, a marked excess of albuminoid ammonia and of oxygen required for organic matter would be fair cause for condemning a water, even if its other characters were good. As it is impossible to lay down rigid rules, something must be left to the discretion and judgment of the observer.

The waters belonging to the first and second class may be used; those of the third, or suspicious class, should be well filtered before distribution, and, if possible, should be again filtered in the house. A purer source should also be obtained if possible, and sources of sewage contamination ascertained and prevented.

The waters of the fourth class should be entirely disused, or only be used when a better source is not procurable, and means of purification (see page 28) should then be systematically resorted to.

## SUB-SECTION III.—ORIGIN OF THE IMPURITIES IN DRINKING WATER.

The origin of the impurities in water may be conveniently referred to four heads, viz., 1. Substances derived from the source; 2. Substances added during the flow of the water in rivers, canals, aqueducts, or other conduits; 3. Impurities caused by storage in reservoirs or tanks; and, 4. Substances added during distribution from reservoirs either in pipes or water barrels, or in house cisterns.

### 1. *Impurities of Source.*

The geological formation of a district necessarily influences the composition of the water running through it, though it is impossible to tell with absolute certainty what the constituents of the water may be. Formations vary greatly, and the broad features laid down by geologists do not always suffice for our purpose. In the middle of a sandy district, yielding usually a soft water, a hard selenitic water may be found; and instead of the pure calcium carbonate water, a chalk well may yield a water hard from calcium sulphate and iron. Still it may be useful to give a short summary of the best known facts.

1. *The Granitic, Metamorphic, Trap Rock, and Clay Slate Waters.*—Generally the granitic water is very pure, often not containing more than two to six grains per gallon of solids, viz., sodium carbonate and chloride, and a little lime and magnesia. The organic matter is in very small amount. The clay-slate water is generally very pure, often not containing more than from three to four grains per gallon. The water from hard trap-rocks is pure, but if the trap be disintegrated the shallow wells sunk in it are of course liable to be fouled by surface washings or soakage.

2. *The Water from Millstone Grit and Hard Oolite.*—Like the granitic water this is very pure, often not containing more than four to eight grains per gallon of mineral matters, which consist of a little calcium and magnesium sulphate and carbonate; a trace of iron.

3. *Soft Sand-Rock Waters.*—These are of variable composition, but as a rule are impure, containing much sodium chloride, sodium carbonate, sodium sulphate, iron, and a little lime and magnesia, amounting altogether to from thirty to eighty grains per gallon. The organic matter may be in large amount,—four to eight grains per gallon, or even more. Sometimes these

waters are pure and soft, or wells or springs, within a short distance, may vary considerably in composition.

4. *The Loose Sand and Gravel Waters.*—In this case there is also a great variety of composition. Sometimes the water is very pure, as in the case of the Farnham waters, and in some of the waters from the greensand, where the total solids are not more than from four to eight grains per gallon, and consist of a little calcium carbonate, sulphate, and silicate; magnesium carbonate; sodium and potassium chloride; sodium and potassium sulphate; iron, and organic matter. The last is sometimes in some amount, viz., ·8 to 1·8 grains per gallon. In tolerably pure gravels, not near towns, the water is often very free from impurity. In the case of many sands, however, which are rich in salts, the water is impure, the solid contents amounting sometimes to fifty or seventy grains per gallon, or more, and consisting of sodium chloride, sodium carbonate, sodium sulphate, with calcium and magnesium salts.[*] These waters are often alkaline, and contain a good deal of organic matter. The water from the sands in the "Landes" (Southern France) contains enough organic matter to give ague.

5. *Waters from the Lias Clays* vary in composition, but are often impure; even 217 grains per gallon of mineral matters have been found. No less a quantity than 88 grains of calcium sulphate, and 41·8 of magnesium sulphate, existed in a water examined by Voelcker.[†]

6. *The Chalk Waters.*—The pure, typical, calcium carbonate water from the chalk is very sparkling and clear, highly charged with carbonic acid, and contains from 7 to 20 grains per gallon of calcium carbonate, a little magnesium carbonate and sodium chloride—small and immaterial quantities of iron, silica, potassa, nitric, and phosphoric acids. Sulphuric acid in combination is sometimes present in variable amount; organic matter is usually in small amount. This is a good, wholesome, and pleasant water. It is hard, but softens greatly by boiling.[‡]

7. *The Limestone and Magnesian Limestone Waters.*—These are also clear, sparkling waters of agreeable taste. They differ from the chalk in containing usually more calcium sulphate (4 to 12 grains, or even more) and less carbonate, and, in the case of the dolomitic districts, much magnesium sulphate and carbonate. Organic matter is usually in small amount. They are not so wholesome as the chalk waters. They are hard, and soften less on boiling.

8. *The Selenitic Waters.*—Water charged with calcium sulphate (6 to 20 grains, or even more) may occur in a variety of cases, but it may sometimes come from selenitic rocks. It is an unwholesome water, and in many persons produces dyspepsia and constipation, alternating with diarrhœa. It is hard, softens little on boiling, and is not good for cooking or washing.

9. *Clay Waters.*—Very few springs exist in the stiff clay; the water is chiefly surface, and falls soon into rivers; it varies greatly in composition, and it often contains much suspended matter, but few dissolved constituents, chiefly calcium and sodium salts.

10. *Alluvial Waters.*—(Alluvium is usually a mixture of sand and clay.)

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[*] In a shallow well (20 feet deep) in the gravel, near NetleyAbbey, the water yielded total solids 148·75, of which were chlorides 86·80, grains per gallon; after deepening it to 80 feet, and passing through a stratum of stiff blue clay, it gave only 16·8 total solids, and 6·5 of chlorides. [F. de C.]

[†] In a well from Weedon Barracks, 109 feet deep, sunk in blue Lias, I found 91 grs. per gallon of solids, but very little organic matter. (F. de C.)

[‡] Sometimes the water drawn from the upper part of the chalk is really derived from tertiary sand lying above the chalk. The water contains less calcium carbonate, and more sodium carbonate and chloride, and may be alkaline.

Generally impure, with calcium carbonate and sulphate, magnesium sulphate, sodium chloride and carbonate, iron, silica, and often much organic matter. Occasionally the organic matter oxidises rapidly into nitrites, and if the amount of sodium chloride is large, it might be supposed that the water had been contaminated with sewage. The amount of solids per gallon varies from 20 to 120 grains, or even more.

11. *Surface and Subsoil Water.*—Very variable in composition, but often very impure, and always to be regarded with suspicion. Heaths and moors, on primitive rocks, or hard millstone grit, may supply a pure water, which may, however, be sometimes slightly coloured with vegetable matter. Cultivated lands, with rich manured soils, give a water containing often both organic matter and salts in large quantity. Some soils contain potassium, sodium, and magnesium nitrates, and give up these salts in large quantity to water. This is the case in several parts of India, at Aden, and at Nassick in the Deccan (Haines). In towns and among the habitations of men, the surface water and the shallow well water often contain large quantities of calcium and sodium nitrites, nitrates, sulphates, phosphates, and chlorides. The nitrates in this case probably arise from ammonia, ammonium nitrite being first formed, which dissolves large quantities of lime. Organic matter exists often in large amount, and slowly oxidises, forming nitric acid and ammonia.* In some cases butyric acid, which often unites with lime, is also formed.

12. *Marsh Water.*—This always contains a large amount of vegetable organic matter; it is not unusual to find from 12 to 40 grains, and in some cases even more. Suspended organic matter is also common. The salts are variable. A little calcium and sodium, in combination with carbonic and sulphuric acids and chlorine are the most usual. Of course, if the marsh is a salt one, the mineral constituents of sea-water are present in varying proportions.

13. *Water from Grave-yards.*—Ammonium and calcium nitrites and nitrates, and sometimes fatty acids, and much organic matter. Lefort found a well of water at St Didier, more than 330 feet from a cemetery, to be largely contaminated with ammoniacal salts and an organic matter which was left on evaporation. The water was clear at first, but had a vapid taste, and speedily became putrid.

14. *Artesian Well Water.*—The composition varies greatly. In some cases the water is so highly charged with saline matter as to be undrinkable; the water of the Artesian well at Grenelle contains enough sodium and potassium carbonates to make it alkaline; in some cases the water contains iron in some amount; in other cases, especially when drawn from the lower part of the chalk, or the greensand below it, it is tolerably pure. Its temperature is usually high in proportion to the depth of the well. The aeration of the water is often moderate, sometimes nil. These last two points rather militate against the employment of water from very deep wells.

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* C. Schmidt (quoted by Roth and Lex) has given the following comparative analysis of the water of Dorpat:—

| | The normal water gives per litre. | The water of the town wells gives per litre. |
|---|---|---|
| Total Salts, . . | ·44820 | 1·16602 |
| $NO_5$, . . . | ·00559 | ·19202 |
| $NH_3$, . . . | ·00046 | ·00188 |
| NaO, . . . | ·00508 | ·07656 |
| KaO, . . . | ·00536 | ·07326 |
| Cl, . . . . | ·00642 | ·11217 |
| $PO_5$, . . . | ·00061 | ·00563 |

In Dresden the same results have been found.

15. *Water from Wells near the Sea.*[*]—This often contains so much saline matter as to taste quite brackish, although the organic matter may not be very large. In some samples from Shoeburyness (analysed at Netley) the total solids ranged from 104 to 218 grains per gallon of total solids, the chlorides being from 22 to 65 : mean of six samples—165 total solids, and 35 of chlorides. In one sample, however, the albuminoid ammonia was only 0·07 per million, and in five the oxygen required for organic matter was under 0·75 per million.

16. *Rain Water* may be contaminated by washing the air it falls through, but more by the surface on which it falls, such as decaying leaves or other matter on the roofs of houses; it also takes lead from lead coatings and pipes, and zinc from zinc roofs.

### 2. *Impurities of Transit from Source to Reservoirs.*

Open conduits are liable to be contaminated by surface washings carrying in finely divided clay, sand, chalk, and animal matters from cultivated land; and the leaves and branches of trees add their contingent of vegetable matters. These impurities may occur in most cases, but in addition the refuse of houses, trades, and factories is often poured into rivers, and all sorts of matters are thus added.

These impurities are broadly divided by the Rivers Pollution Commissioners into "sewage" and "manufacturing;" under the former term all solid and liquid excreta, house and waste water, and in fact all impurities coming from dwellings are included; under the latter term are placed all manufacturing refuse, such as from dye and bleach works, tanneries, paper-making, woollen, silk, and metal works, &c.[†]

The very numerous animal and vegetable substances derived from habitations are usually classed under the vague, but convenient term of "organic matter," as the separation of the individual substances is impossible. The organic matter is usually nitrogenous, and Frankland has proposed to express its amount in terms of its nitrogen (organic nitrogen), but this view is not yet generally received on account of the difficulty of estimating the very small quantity of nitrogen. The nitrogenous organic matter undergoes gradual transformation, and forms nitrous and nitric acids and ammonia. The exact steps of this process are perhaps complicated. On keeping the water the nitrites disappear, and in some cases the nitrates also gradually diminish, perhaps from the action of bacteria. A. Müller[‡] found the residue of a well water gave with soda hydrate a herring-like odour, which seemed like trimethylamine.

Many of the "organic matters" in water are not actually dissolved, but are so finely suspended that they pass through filtering paper. There is no doubt that among this "suspended organic matter" many small plants and animals are always included. It is probably owing to the variation in the quantity of suspended organic matter (living and dead) that water from the same source sometimes gives different results on analysis, even though the water be taken at the same time. During its flow in open conduits, however, a species of purification goes on, by means of subsidence, the action of water-plants, and to some moderate extent by oxidation. On the whole, these processes appear in India to render river water, in spite of all the contaminations it receives, purer than tank and well water.[*] The freedom from noxious substances is also apparently greater in India in the quick running streams, which may also depend upon purification taking place in them.[†]

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[*] For a good example of the influence of a tidal river on neighbouring wells, see my "Lectures on State Medicine," Table x. p. 91. [F. de C.]

[†] For a full account of all these impurities, and the best mode of dealing with them, the six Reports of the Rivers Pollution Commissioners must be referred to.

[‡] Roth and Lex, Militär-Gesundheitspfl. p. 16.

### 3. *Impurities of Storage.*

The chance of substances getting into the water of wells, and tanks,[‡] and even of cisterns in houses is very great. Surface washings and soakage contaminate wells and tanks, and leakages from pipes, passage of foul air through pipes, or direct absorption of air by an uncovered surface of water introduce impurities into cisterns.[§] It is singular in how many ways cisterns and tank waters get foul, and what care is necessary not only to place the cistern under safe conditions at first, but to examine it from time to time to detect contamination of the water. In India, especially, the tank water is often contaminated by clothes washed near, or actually in, the tank; by the passage even of excrement directly into it, as well as by surface washings, so that in fact in some cases the village tank is one of the chief causes of the sickness of the people. There is, perhaps, no point on which the attention of the sanitary officer should be more constantly fixed than that of the storage of water, either on the large or small scale.

In shallow wells (4 to 30 feet deep) the soakage water from the ground in loose soils of chalk and sand is often very impure. Thus in a town the well water often shows evidence of nitrites and nitrates and ammonia, and of chlorine far in excess of river water in the neighbourhood, though the strata are the same.[‖] Occasionally, by constant passage of the water, a channel is formed, which may suddenly discharge into the well; and some of the cases of sudden water poisoning have thus arisen.

A well drains an extent of ground about it in the shape of an inverted cone. The area must depend on the soil; in very loose soils a well of 60 to 80 feet may perhaps drain an area of 200 feet in diameter on the surface, but this must be considered as only a rude estimate. Professor Ansted states that the deepest (non-Artesian) well will not drain a cone which is more than half a mile in radius.

In some cases a well at lower level may receive the drainage of surrounding hills flowing down to it from great distances. Good coping stones, so as to protect from surface washings; good masonry for several feet below the surface of wells in very loose soils, so as to prevent superficial soakage, are necessary in all shallow wells.

### 4. *Impurities of Distribution.*

If water is distributed by hand, *i.e.*, by water-carts, barrels, or skins, there is necessarily a great chance of its being fouled. In India, where the water is generally carried by water-carriers (Bhisties), inspection of the carts or skins should be systematically made, and whenever it be possible, pipes should be substituted for the rude method of hand conveyance. But even pipes may contaminate water; metals (lead and iron) may be partly dissolved; wood rots, and if the pipes are occasionally empty impure air may be drawn into them, and be afterwards absorbed by the water.[*] I have been informed that in towns supplied on the constant system, when the pipes are becoming empty the flow of water from a tap has drawn foul water or air through a pipe at some distance, and in this way even the water of the mains has been befouled.

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[*] Palmer shows this clearly in a very interesting paper in the "Indian Medical Gazette" for December 1870.

[†] Much influence has been ascribed to oxidation, and doubtless in part correctly; but Dr Frankland has shown its effect to be limited. The Irwell river, after passing Manchester, runs 11 miles to its junction with the Mersey without further material pollution, and falls over 6 weirs; yet the purification by oxidation is trifling. By syphoning water from one vessel to another so as to represent a run of 96 miles, the organic carbon was only reduced 6·4 per cent. and the organic nitrogen 28·4 per cent.

[‡] In two examples of (so called) rain-water collected in tanks in the marsh near Tilbury Fort for the use of the troops, the solids were found to be respectively 41 and 145 grains per gallon (Army Medical Reports, vol. xvii. p. 214).

[§] A good case of absorption by an open cistern of gases from water-closets and urinals is recorded by Druitt ("Medical Times and Gazette," September, 1869). The water as supplied contained ·08 parts per million of albuminoid ammonia; after absorption, ·17 parts.

[‖] Roth and Lex, Mil-Gesundsh. p. 43.

Coal gas passing into the ground from leaking of gas pipes sometimes finds its way into wells, or even into water pipes, though examples of this kind must be rare. In Berlin, in 1864, out of 940 public wells, 39 were contaminated by admixture with coal gas. A good instance is related by Mr Harvey,[†] where the main pipes were often empty and gas penetrated into them. Having regard to the cases in which gases from the soil (from leaking gas pipes, sewers, &c.) find their way into water pipes, it would seem important not to lay down water pipes near any other, or, what is better, have all pipes in sub-ways where they can be inspected.

## SECTION III.

## PURIFICATION OF WATER.

### *Without Filtration.*

1. *Exposure to Air in divided Currents.*—This was a plan proposed by Lind, for the water of the African west coast, more than 100 years ago, and frequently revived since. The water is simply poured through a sieve, or a tin or wooden plate, pierced with many small holes, so as to cause it to fall in finely divided streams, or a hand-pump is inserted in a cask of water, and the water is pumped up, and made to fall through perforated sheets of tin. It soon removes hydrosulphuric acid, offensive organic vapours, and, it is said, dissolved organic matter. The same plan has been used in Russia on a large scale, the water being allowed to fall down a series of steps, passing through wire gauze as it does so. In Paris, also, it has been employed on the small scale.

2. *Boiling and Agitation.*—This plan gets rid of calcium carbonate, iron in part, and hydrosulphuric acid, and lessens, it is said, organic matter. It is uncertain how far boiling will destroy the poisons of the specific diseases. It will not destroy bacteria, or at least their germs still live, and Lex found some bacteria still moving rapidly, at a temperature of 127° C.[‡] Most fungus spores are killed by boiling.

3. *Aluminous Salts.*—Alum has been used for centuries in India and China, to purify water from suspended matters. It does this very effectually, if there be calcium carbonate in the water; calcium sulphate is found, and this and a bulky aluminium hydrate entangle the floating particles and sink to the bottom. Mr Alfred Bird has proposed aluminium tersulphate, which is equally efficacious; it is an acid liquid, containing about ·4 grains of the sul-

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[*] Cases of this sort are given in the reports of the medical officer of the Privy Council No. ii. new series. See Dr Bloxall on fever at Sherborne, Dorset, and Dr Buchanan on the fever at Caius' College, Cambridge. In the latter case *foul trap-water* was sucked in from the closets.

[†] Food, Water, and Air, February 1872, p. 68.

[‡] It seems improbable that any germ or organism should resist the temperature of boiling water, if every part of it be thoroughly heated to that point. The apparent resistance may perhaps be due to some *spheroidal* condition the organism may be capable of assuming. Sanderson puts the death-point of common septic Bacteria at about, 110° C or 230° F. (F. de. C.)

phate in each minim; and M. Bellamy* has also proposed a modification of the alum process, by adding additional potash to a solution of alum till the precipitate is redissolved. The quantity of crystallised alum to be used should be about 6 grains per gallon; of Mr Bird's fluid (sulphate of alumina), 20 drops.

From numerous experiments on purifications with crystallised alum, and with Mr Bird's patent liquid, I found the following effect to be produced, with and without calcium carbonate in the water:—

*Effect on Artificial Sewage Water of different composition, the Sewage Matter being partly dissolved partly suspended.*

| | Grains of volatile matter per gallon. | Grains of oxygen required to oxidise at 140° F., and in the presence of sulphuric acid, per gallon. |
|---|---|---|
| 1. Distilled water, containing volatile sewage matter and 8 grains of calcium carbonate per gallon, . . . . . | 8·8 | 1·050 |
| Same as above, after precipitating with 9 grains of crystallised alum per gallon . | 3·85 | ·350 |
| Same, with 18 minims of Bird's patent liquid (aluminium sulphate), . . | 4·20 | ·638 |
| 2. Distilled water, with sewage, but with only 2·1 grains calcium carbonate per gallon, | 27·44 | |
| Same as No. 2, with 18 minims of Bird's patent fluid. . . . . | 23·8 | |
| Same as No. 2, with 54 minims of Bird's patent fluid, . . . . | 21·0 | |
| 3. Distilled water, without calcium carbonate, the sewage matter being almost entirely dissolved and not suspended, . . | 5· | ·805 |
| Same, with 6·8 grains of crystallised alum, | 4·76 | ·700 |
| 4. Same water as No. 3, but with 5 grains of calcium carbonate, . . . . | 5· | ·805 |
| Same, with 20 drops of Bird's liquid, . | 4·02 | ·595 |
| Same, with 6·8 grains of crystallised alum | 4·76 | ·595 |

It is clear from these and other experiments, not only that calcium carbonate ought to be in the water, but that the action of both alum and Bird's fluid is made more upon the suspended organic matters than upon those actually dissolved; and, indeed, having regard to the great difficulty of insuring that water is actually free from minute suspended matters, it is even a question whether aluminous salts will act in any appreciable degree on dissolved organic matters. But on suspended matters, both organic and mineral, the effect is very great indeed. Common alum and Bird's liquid seemed to me practically equal; but alum, being solid, is more convenient for transport.†

If a sedimentous water is extremely soft, a little calcium chloride and sodium carbonate should be put in before the alum is added.

4. *Addition of Lime Water* (Clark's patent).—By combining with carbonic

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* Comptes Rendus de l'Acad., Nov. 11, 1867, p. 799.

† The head-quarter wing of the 92d Highlanders, going up the Indus in 1868, suffered from diarrhœa from the use of the water; the left wing used alum and had no diarrhœa. The right wing then used it and the diarrhœa disappeared.—*Indian Medical Gaz.*, Aug. 1869, p. 158.

*acid, it causes almost all the calcium carbonate previously and newly formed to be thrown down. It also throws down suspended and perhaps dissolved organic matters, and also, it is said, iron. It does not touch calcium and magnesium sulphate and chloride.*[*]

5. *Sodium Carbonate*, with boiling, throws down lime, and possibly a little lead, if present.

6. *Addition of Potassium or Sodium Permanganate* (Condy's red fluid).—I have made some experiments with pure Condy's fluid to determine the value of the permanganate. It certainly readily removes the smell of sulphuretted hydrogen and the peculiar offensive odour of impure water which has been kept in casks or tanks. If it forms a precipitate of manganic oxide, it also carries down suspended matters; but the formation of this precipitate is very uncertain. The action on the dissolved organic matters will of course vary with the nature of the substance; some of the organic matters, both animal and vegetable, will be oxidised;[†] but it will not in the cold act even upon the whole of these substances, and some organic matters are not touched.

One objection to the use of the permanganate is that it often communicates a yellow tint to the water, arising from suspended finely divided peroxide of manganese. This is probably of no moment as far as health is concerned, but it is unpleasant. Sometimes the addition of a little alum will carry down this suspended mater; boiling may be used, but often has no effect. Sometimes nothing removes it but charcoal filtration.

The indications for the use of permanganate are these. In the case of any foul-smelling or suspected water, add good Condy's fluid, teasponful by teaspoonful, to 3 or 4 gallons of the water, stirring constantly. When the least permanent pink tint is perceptible, stop for five minutes; if the tint is gone, add 36 drops, and then, if necessary, 30 more, and then allow to stand for six hours; then add for each gallon 6 grains of a solution of crystallised alum, and if the water is very soft, a little calcium chloride and sodium carbonate, and allow to stand for twelve or eighteen hours. If not clear, or if discoloured, filter through charcoal.

There are many cases in which this plan may be useful; and as the permanganate certainly removes smells and oxidises in the cold to some extent, it is a very good introduction to the alum process, and does work which alum alone will not do. But it cannot be considered a complete purifier of water from all organic matters. Its oxidising power is, however, very useful in cleaning filters, as will be presently noted.

7. *Perchloride of Iron.*—It has been found that the water of the Maas in Holland, which is turbid from clay and finely suspended organic matters, and gives rise in consequence to diarrhœa, is completely purified by perchloride of iron in the proportion of about 2½ grains of the solid perchloride to 1 gallon of water.[‡]

*Use of the Strychnos potatorum.*—In India the fruit of the *Strychnos potatorum* is used, especially by the better class of Hindoos, to purify water. It is beaten into a paste, and rubbed on the inside of the water jar or cask. Dr Mouat informs me that it is chiefly used for the river water at the seasons when it is laden with silt, and that about 30 grains are used for 100 gallons of water, which act in twenty-four hours. Its action appears to be on suspended matters, which it possibly carries down by giving to the water a delicate albuminous coagulum, so that it purifies water on the same principle as beer is fined.[*] Dr O'Shaughnessy thought its action was connected with its astringency. I have made some experiments on its action, but without any satisfactory result. I did not even find it cleared the water thoroughly from suspended matters, and it had no effect on the amount of nitrous acid, ammonia, or of oxidisable organic matters, as far as these could be judged of by potassium permanganate. Renewed experiments are, however, necessary.

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[*] This plan has been recently tried with great success on a large scale, as, for instance, in the Colne valley water works.

[†] I have not been able to satisfy myself that I could detect either nitric or nitrous acid after the treatment of dissolved sewage by alkaline premanganate. According to Schulze oxalic acid is formed.

[‡] Chemical News, May 1869, p. 239.

8. *Immersion of Iron Wire and Magnetic Oxide of Iron* (Medlock).—This plan is said to decompose organic matter. Charcoal and ferric oxide are sometimes mixed.

9. *Immersion or boiling of certain Vegetables*, especially those containing tannin, such as tea,[†] kino, the Laurier rose (*Nerium Oleander*, which is also rubbed on the inside of casks in Barbary), bitter almonds (in Egypt).

10. *Immersion of small pieces of Charcoal, and charring the inside of Casks.*—This is an extremely effectual plan, but the charcoal soon loses its power, and requires to be renewed. Berthollet considered that the charring of the casks was more effectual than the immersion; the charring can be renewed from time to time. Löwitz advises that a little sulphuric acid (10 drops to 1 lb. of charcoal) shall be added. A mixture of some of these substances has been used, as lime and alum (1 part to 2), or carbon and alum (4 parts to 1).[‡]

To put these facts in another form:—

*Organic matter* is got rid of most readily by exposure to air, boiling, agitation, charcoal, alum, potassium permanganate, astringents.

*Carbonate of Lime*, by boiling and addition of caustic lime.

*Sodium chloride*, by filtration through a great depth of charcoal or sand.

*Iron*, by boiling and lime water, and in part by charcoal. Lead and copper are also removed or lessened by pure charcoal.[§]

*Calcium and magnesium sulphate and chloride* cannot be got rid of, but are perhaps lessened a little by filtration through charcoal.

It should also be remembered that some water plants have a purifying effect, apparently from the large quantity of oxygen they give out; and this takes place sometimes though the water itself is green.

### *With Filtration.*

*Sand and Gravel.*—On the large scale, water is received into settling reservoirs, where the most bulky substances subside, and is then filtered through gravel and sand, either by descent or ascent, or both.[||]

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[*] Pereira, Pharmaceutical Journal, vol. ix. p. 478.

[†] In the north of China, and especially during winter, the water of the Peiho becomes very impure, and contains not only suspended matters, but dissolved animal matter in large quantity which gives the water a disagreeable offensive smell. The Chinese never drink it except as tea which is cooled with a lump of ice, if it is desired to drink it cold. In this way they secure themselves from all bad effects of this water (Friedel, Das Klima Ost-Asiens, p. 60). The Europeans use alum and charcoal; but these do not always entirely remove the taste. The Tartars also use their "brick tea" to purify the water of the steppes, which would otherwise be undrinkable.

[‡] Surgeon-Major W. Harvey has tried with good effect the immersion of one or two bags of charcoal in a stream, so that the water should pass through the bags.

[§] Chevalier, Traité des Désinfect., p. 147. In the Ashanti campaign, under the directions of Surgeon-Major V. Gouldsbury C.M.G., the water was purified in the following way, in the absence of proper filters:—Alum was added to precipitate suspended matter—the water was passed through a rough filter, consisting of (1.) sponge; (2.) sand; (3.) charcoal in pieces; it was then boiled, and a few drops of solution of potassium permanganate added. Water, even taken from a hole in a marsh, was innocuous after this treatment.

[||] A good account of the engineering plans and filtration of the London Water Companies

The London water companies usually employ a depth of 3 to 5 feet; in the latter case, the upper stratum of 18 inches or 2 feet is composed of sand, the lower 3 feet are made up of gravel, gradually increasing in coarseness, from pieces the size of a small pea and bean to that of a middle-sized potato. A stratum of oyster shells, about 1½ inch in thickness, has been used by some companies instead of a layer of gravel, but this plan is not general. If the filter is 3 feet in thickness, the upper 15 inches are sand, and the lower 21 inches are gravel.

The pressure of water in these filters is not great; the depth of the water is never above 2 feet, and some companies have only 1 foot; from 70 to 75 gallons is the usual quantity which should pass through in 24 hours for each square foot; but some companies filter more quickly, viz., at the rate of a gallon per 24 hours for each square inch, or 144 gallons per square foot.

The sand should not be too fine; the sharp angular particles are the best. The action seems chiefly, perhaps altogether, mechanical; the suspended impurities, both mineral and organic, rub upon and adhere to the angles and plane surfaces of the sand, which are gradually encrusted, and after a certain time the sand has to be cleaned. The effect on suspended matters, both organic and mineral, is certainly satisfactory. On dissolved organic matter it is less so.* Mr Witt's experiments show only a removal of about 5 per cent.

I have made some experiments on a sand filter of 1 square foot surface, and made in imitation of a London water company's filter, viz., 15 inches of fine, well-washed white sand, and 20½ inches of gravel, gradually increasing in coarseness. The first eight gallons were thrown away, so as to avoid the fallacy of including the distilled water with which the sand had been washed.

This sand filter had the following effect, as shown by the table:—

It took away three-quarters of the colour.

| | |
|---|---|
| It lessened the total solids by . . . . . | 7·063 grains. |
| „ „ mineral solids by . . . . | 4·703 „ |
| „ „ volatile solids by . . . . | 2·36 „ |
| „ „ total amount of oxygen required for oxidation by nearly half, or . | ·1546 „ |
| „ „ hardness by . . . . . . | 4°·61 |
| „ „ chlorine by . . . . . . | 0·6 |
| „ „ free ammonia . . . . . | ·0042 |
| „ „ albuminoid ammonia . . . . | ·0126 |

These experiments also showed that the effect of the sand in arresting lime salts was limited; it stopped organic matter after it had ceased to arrest lime. After a longer time it became useless, and required washing.

It is yet uncertain whether the action of sand on organic matter is at all chemical, *i.e.*, whether the organic matter is oxidised in its transit; considering what an amount of air is contained in the interstices of sand, and how finely the water is divided in its transit, some amount of oxidation is probable, but good chemical evidence is yet wanted. Mr Shield's experiments, given in the note, seem to me opposed to the probability of much chemical action. On dissolved mineral matters sand exerts at first, and when in thick layers, a good

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will be found in a work called "The Water Works of London," by Messrs Colburn & Shaw, 1867.

* In a sand and gravel filter, 33 inches in thickness, Mr. Shield (Proc. Inst. of Civil Engineers for 1867); gives the following numbers:—The original amount of organic matter being ·8906 grains per gallon, the amount after filtration was as follows—after 23 hours action, 1·012; after 120 hours, ·648; after 240 hours, ·917; after 376 hours, ·809. So that, while on the whole the sand removed some organic matter, the amount was really inconsiderable.

deal of action; much sodium chloride can be removed; and Professor Clark has stated that even lead can be got rid of by filtering through a thick stratum. Very finely divided clay seems to pass through more readily than any other suspended matters.*

The fine white sand is the best; it should be chosen carefully, and well washed, and, if possible, heated to redness before use.

Instead of sand and gravel, trap rock has been used.

*Sponge.*—Sponge has a considerable effect in mechanically arresting suspended particles. I took two sponges, weighing 255 and 155 grains, and pressed them into glass funnels; 11 gallons of sedimentous water of known composition were passed through each sponge. The total sediment in the 11 gallons weighed 273·7 grains; the larger sponge removed 257 and the smaller 252 grains. On dissolved matters sponge has little effect, as shown in the next table. Three sponges, weighing 611, 409, and 365 grains, were taken, and an artificial sewage water was poured slowly through.

| | Grains per Gallon. | | | |
|---|---|---|---|---|
| | Total Solids. | Mineral Solids. | Destructible Solids. | Oxygen required for oxidation. |
| Unfiltered, . . . . . | 18·2 | 4·2 | 14 | 2·80 |
| Filtered through largest sponge, | 17·5 | 5·6 | 11·9 | 2·66 |
| Filtered through middle-sized sponge, . . . . | 18·2 | 4·2 | 14 | 2·75 |
| Filtered through smallest sponge, | 17·5 | 5·6 | 11·9 | 2·80 |

*Animal Charcoal.*—Pure animal charcoal (deprived of calcium phosphate and carbonate by washing or by hydrochloric acid) is now considered one of the best filtering materials. The particles of charcoal should be well pressed together, and the passage of the water should not be too quick. Contact with the water for about four minutes appears about the best time.† There is a general agreement that there is a large removal of suspended matters, both mineral and organic; water even deeply tinged comes through a good charcoal filter very clear and bright. So also there seems no doubt that some dissolved organic and mineral matters are also removed by charcoal in the first instance. All evidence agrees in respect of that point. But a serious difference of opinion exists as to the mode and permanence of action of animal charcoal.

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* A peculiar difficulty, never experienced in England, has been discovered in the filtering, through sand, of the Hooghly water at Calcutta; during the rainy season the fine mud brought down penetrates very deeply into the filters, and rapidly chokes them; in the dry season this does not happen; the suspended matters are arrested, as in England, near the upper surface of the sand. Mr D. Waldie (Journal of the Asiatic Society of Bengal for 1873, part II, p. 210.) explains this by showing that in the rainy season the water contains much less saline matter than in the dry season; it is this saline matter which seems to act on and so cause coherence of the particles of mud, so that they become larger and coarser, and are more easily arrested. In order to remedy this, Mr. Waldie proposes the addition of substances to the water during the rains, which may cause this coalescence; he has tried a great number of experiments and different substances, on the whole crystallised alum and perchloride of iron are the best; 55·4 ℔ of crystallised alum, or 19·15 ℔ of perchloride of iron, were found to be necessary for the clarification of one million gallons of muddy Hooghly water during the rainy season.

† On this point there is some difference of opinion, as will be seen on reference to the debates on Mr Byrne's paper in the Proceedings of the Institution of Civil Engineers for 1867. Dr Letheby advocates a slow filtration, while Dr Frankland considers that a rapid flow is sufficient; on passing 41,000 gallons in one day through coarse charcoal, 3 feet in thickness, he found half the organic matter removed. With a head of 22½ feet of water, he has passed, in 24 hours, as much as 90,734 gallons per square foot through 34 inches of charcoal; but in this case the purifying effect is not stated. Dr Frankland has therefore recommended that the water supply of a town shall be filtered through animal charcoal. The cost, however, would be large, though there is no doubt the water can be got through at a sufficient rate.

Thus, Mr Byrne* has shown that with a filter of charcoal weighing 4¾ lbs., through which 12 gallons of water (containing 10·8 grains of organic matter per gallon) were passed in 24 hours, the purifying effect was equal to a removal of 55½ per cent. of the organic matters from the first gallon, but this gradually declined until at the fourth gallon only 1·33 per cent. was removed, and at the eighth gallon the action was reversed, and organic matter was given back to the water. Exception has been taken in two ways to this experiment—first, as regards the chemical proof of the organic matter, and secondly, as to the inference drawn from the experiment. As regards the first point, it appears to me difficult to set aside Mr Byrne's facts, and I think they must be accepted; as regards the second point, instead of the animal charcoal exerting no action, it might have been simply called on to do more than could be expected; for the purifying effect of no substance is inexhaustible.† This supposition does not appear probable, however, as only 43 grains of organic matter had gone through 4¾ lbs. of charcoal before the purifying power of the charcoal was virtually exhausted. The inference from Mr Byrne's experiments is supported by a statement by Mr Chapman,‡ who recovered from charcoal the amount of organic matter which had been previously removed by it from a water. This would almost seem to settle the point, were it not that there is strong and apparently indisputable evidence on the other side. In the debate on Mr Byrne's paper, both Dr Letheby and Dr Frankland brought forward facts to show that animal charcoal not merely arrests but chemically changes organic matter, and that this power is retained for a long time. Thus Dr Letheby obtained some charcoal which had been in use for two years, and through which it was calculated 292,000 gallons had passed. The charcoal still deprived water of colour and of organic matter, as judged of by permanganate and distillation with potash for ammonia. The charcoal being then analysed, gave the following results:—

| | | | | | |
|---|---|---|---|---|---|
| 4 ounces | from | top of filter | gave | ·321 | grains of ammonia. |
| ,, | ,, | middle | ,, | ·162 | ,, ,, |
| ,, | ,, | bottom | ,, | ·240 | ,, ,, |

The organic matter had not then accumulated; what had become of it? Water with organic matter having passed through this old charcoal, nitrites appeared in the filtrate. It had therefore been oxidised.

Dr Frankland's experiments were made on water containing small quantities of organic matter, but showed permanence of action after 5000 gallons had gone through.

Taking these experiments in connection with the older experiments of Witt, which showed a removal of 88 per cent. of organic matter, and with those of Gaultier de Claubry, and with the numerous experiments on charcoal filters, the reading of the facts seems to be that charcoal must have a chemical

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* Proceedings of the Institution of Civil Engineers for 1867.

† From experiments at Netley, conducted by Mr Sylvester, Apothecary to the Forces, it was found easy to foul charcoal by passing through it a strong solution of organic matter; but the power was easily restored by cleansing the filter with a little potassium permanganate. The cessation of power must depend upon the relative amount of the organic matter and charcoal, but the quantitative relations were not settled.

‡ Made in the debate on Mr Byrne's paper. See Proceedings of the Institution of Civil Engineers for 1867. Mr Shield's experiments on charcoal, the size of walnuts, recorded in the same debate, give the following result:—

| | Original water. | After 67 hours. | After 91 hours. | After 115 hours. | After 139 hours. |
|---|---|---|---|---|---|
| Amount of organic matter, | 1.430 | ·475 | ·478 | ·620 | ·971 |
| Percentage removed, | ... | 66·780 | 68·000 | 56·670 | 32·100 |

Charcoal in granules did not act quite so well.

as well as a mechanical effect, but that the limits of purification are sooner reached than was supposed, if the organic matter be large, so that a more frequent cleansing is required. When, however, the amount of organic matter is small (under 1 or 2 grains per gallon), the action is very permanent. Dr Frankland has suggested that there may be two kinds of organic matter in water, one of which is not acted on by charcoal.*

*Vegetable and Peat Charcoal.*—The effect of both these is decidedly inferior to animal charcoal † (Frankland and Byrne).

*Sea-weed Charcoal* is said to be efficacious.

*Iron and Charcoal.*—Animal charcoal mixed with spongy iron obtained from the refuse of copper pyrites is a very good purifier; also spongy iron in combination with coarse sand and pyrolusite.

*Domestic Filters.*—On a small scale, a number of substances have been used, such as animal and vegetable charcoal made into blocks, or fine silica impregnated with charcoal (silicated carbon filters), hæmatite and magnetic iron ores, the so-called magnetic carbide, spongy iron, manganic oxide, flannel, wool, sponges, porous sandstones (natural and artificial), &c.

The Souchon filters, which are much employed in Paris, are made of diaphragms of wool, which is partially tanned by boiling in solution of alum and cream of tartar, then dyeing in infusion of gall-nuts, and washing in solution of sodium carbonate. The filter of M. Fonvielle, also used in Paris, is composed of nine layers of sponges, pounded sandstone, and gravel.

The best filters now in the market are made either of animal charcoal, of the so-called magnetic carbide of iron, or of spongy iron. I have examined a number of filters of this kind, but, for obvious reasons, I do not wish to give either the names of the makers or the tabular results. I found, however, that in most cases the action was very satisfactory. Suspended matters were almost entirely removed, and a considerable amount of dissolved organic matters was also taken out, and the action seemed to continue if no excessive impurity was used. Individual filters, even from the same maker, differ in their action; but on an average there is no charcoal or magnetic carbide filter now in the English market which cannot be relied on to remove 40 per cent. of dissolved organic matter, and in some cases it is much more;‡ the amount of nitrites, ammonia, and of hardness (chiefly carbonate of lime) is also lessened, and chloride of sodium is arrested by several filters to some extent. On the whole, a very useful purifying effect is produced even on dissolved matters, and it is hardly conceivable that, in the best charcoal, carbide, or spongy iron domestic filters, any ova or even smaller living substance could pass through.§

*Cleansing of Filters.*—But there is a limit to all purifying powers, and the action of all filters is therefore temporary.‖ After a time, which depends on the amount of impurity of the water, they become clogged; the substances which block them are organic matters (probably suspended) and lime salts. Sodium chloride, after being arrested for some time, may be given off again, and thus seldom long remains in a filter. Instead of taking the filter to pieces when they are clogged, the following plan may be resorted to:—Every two or three months (according to the kind of water) air should be blown through, and if the charcoal be in the block form it should be brushed. Then 4 to 6 ounces of the pharmacopœial solution of potassium permanganate, or 20 to 30 grains of the solid permanganate in a quart of distilled water, and 10 drops of strong sulphuric acid, should be poured through, and, subsequently, a quarter to half an ounce of pure hydrochloric acid in 2 to 4 gallons of distilled water. This both aids the action of the permanganate, and assists in dissolving manganic oxide and calcium carbonate. Three gallons of distilled or good rain water should then be poured through, and the filter is fit again for use. This plan would be useful on foreign stations, where the filter cannot be sent home or taken to pieces; if it can be taken to pieces, the charcoal should be spread out in a thin layer, and exposed for some time to air and sun, or heated in an oven. If sponges are at all used, they should be removed from time to time, and thoroughly washed in hot water. If the filtering material is composed of a solid plate or ball, the surface should be brushed or scraped.

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* The condition of the organic matter is also important, for it has been shown that fresh albumen passes through unchanged, whilst about 95 per cent. is arrested when it has begun to decompose. (See note by Dr J. L. Notter, Sanitary Record, Oct. 1876, p. 288.)

† Frankland, indeed, seems to consider wood charcoal useless. (Proceeding of Inst. Civil Engineers, 1867.) Debate on Mr Byrne's paper.

‡ I examined six filters from one maker, and found the average removal of organic sewage matter to be 74·5 per cent.; the greatest being 96, and the least 56·2 per cent. The action was also fairly permanent, though cleansing was sometimes necessary.

§ It is right, however, to call attention to the remarks in the sixth Report of the Rivers Pollution Commissioners, where they say that, "the property, which animal charcoal possesses in a high degree, of favouring the growth of the low forms of organised life, is a serious drawback to its use as a filtering medium for potable waters."—I have seen some confirmation of this in experiments made at Netley, and it shows the necessity of renewal of the filtering materials at short intervals. (F. DE. C.)

‖ At the Hygienic Congress at Brussels (August 1876), I found that some of the Continental chemists were so impressed with the dangers arising from impure filters, that they were inclined to doubt the advisability of filtration at all.—(F. DE. C.)

If the charcoal can be taken out it should be washed, then boiled with a little Condy's fluid, then spread out in the sun or in an oven and dried. If means exist it can be re-burnt. All kinds of charcoal, and, of course, most domestic filters, give off at first some substances to water; a certain amount of preliminary washing out with pure water is desirable.* Among other substances, calcium phosphate is taken up from animal charcoal, and even with a minute quantity the water will not act on lead (Frankland).

Small filters, as now sold in the market, may be divided into several kinds:—

1. Syphon cistern filters, which are placed in the water to be purified, and through which the water rises. The filter is often put in the cistern, and, of course, the delivery-pipe always contains freshly filtered water. A very good one of this kind made of animal charcoal has been lately proposed by Dr F. N. Macnamara, of Calcutta, and is likely to be of great service in India. It is now in use in the Bengal Presidency.

2. Pipe filters, in which the filter is placed in the course of the delivery pipe; the effect is the same as with the syphon, but the flow may be quicker, as a greater pressure can be obtained. Both of these plans are very useful.

3. Common domestic filters, of various kinds, filled by hand.

4. Pocket filters, usually of the syphon kind, or made of a hollow block of charcoal, with a tube passing into the interior cavity, the water passes from without into the cavity.

5. Ship filters.—Major Crease, R.M.A., has arranged a very useful tank filter for ships; it is an iron box, cemented inside by a process patented by Major Crease, and divided into two parts by a partition; on one side are 10 to 12 inches of sand, on the other is a corresponding amount of animal charcoal, or charcoal is placed on both sides; a plate and screw lies on both sand and charcoal, so that they can be compressed to any desired extent; and the water

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* I have found that an interchange sometimes takes place in a filter. I passed some calcium sulphate and nitrate water through a new charcoal filter; the sulphuric acid was entirely removed, and the nitric acid partly so; their place was taken by phosphoric acid. It has occurred to me whether a selenitic water might not be made more wholesome by thus substituting phosphoric acid, by leaving the calcium phosphate in the charcoal, or supplying it from time to time.

enters on one side, passes down through the sand, and ascends through the charcoal. I have examined this filter carefully and find its power to be very great. It removes oily matter, which is so often found in condensed water, and both the sand and charcoal are easily taken out and cleaned. He has also introduced smaller filters for barrack use, which are extremely good, and are excellent for ambulance and field use (see figs. 9 and 10). Of the tank filters used in the Ashanti war, Dep.-Surg.-General Sir A. D. Home, K.C.B., V.C., reports: "For effectiveness in perfectly filtering water in large quantities, and for the ease with which the filtering substance could be cleansed, those tanks left nothing to be desired." (Army Medical Reports, vol. xv. p. 247.)

[illegible]

## SECTION IV.

## EFFECTS OF AN INSUFFICIENT OR IMPURE SUPPLY OF WATER.

### SUB-SECTION I.—INSUFFICIENT SUPPLY.

The consequences either of a short supply of water for domestic purposes, or of difficulty in removing water which has been used, are very similar. On this point much valuable information was collected by the Health of Towns Commission in their invaluable Reports.* It was then shown that want of water leads to impurities of all kinds; the person and clothes are not washed, or are washed repeatedly in the same water; cooking water is used scantily, or more than once; habitations become dirty, streets are not cleaned, sewers become clogged; and in these various ways a want of water produces uncleanliness of the very air itself.

The result of such a state of things is a general lowered state of health among the population; it has been thought also that some skin diseases—scabies, and the epiphytic affections especially—and opthalmia in some cases, are thus propagated. It has also appeared to me that the remarkable cessation of spotted typhus among the civilised and cleanly nations is in part owing, not merely to better ventilation, but to more frequent and thorough washing of clothes.

The deficiency of water leading to insufficient cleansing of sewers has a great effect on the spread of typhoid and of choleraic diarrhœa; and cases have been known in which outbreaks of the latter disease have been arrested by a heavy fall of rain.

Little is known with certainty of the effects produced on men by deficiency in the supply of water. Under ordinary circumstances, the sensation of thirst, the most delicate and imperative of all our feelings, never permits any great deficiency for a long time, and the water-removing organs eliminate with wonderful rapidity any excess that may be taken, so as to keep the amount in the body within certain limits. But when circumstances prevent the supply of water, it is well known that the wish to drink becomes so great, that men will run any danger, or undergo any pain, in order to satisfy it. The exact bodily condition thus produced is not precisely known, but from experiments on animals and men, it would appear that a lessened amount of water in the body diminishes† the elimination of the pulmonary carbonic acid, the intestinal excreta, and all the important urinary excreta.

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* First and second Reports (with evidence) of the Health of Towns Commission, 1844 and 1845.

† The experiments of Falck and Scheffer on animals, and of Mosler on men and women, are here referred to.

The more obvious effects produced on men who are deprived for some time of water is, besides the feeling of the most painful thirst, a great lowering of muscular strength and mental vigour. After a time exertion becomes almost impossible, and it is wonderful to see what an extraordinary change is produced in an amazingly short time if water can be then procured. The supply of water becomes, then, a matter of the most urgent necessity when men are undergoing great muscular efforts, and it is very important that the supply should be by small quantities of water being frequently taken, and not by a large amount at any one time. The restriction of water by trainers is based on a misapprehension: a little water, and often, should be the rule. (See EXERCISE.)

### SUB-SECTION II.—IMPURE SUPPLY.

At present, owing probably to the difficulty of making analyses of waters, the exact connection between impure water and disease does not stand on so precise an experimental basis as might be wished. There are some persons who have denied that even considerable organic or mineral impurity can be proved to produce any bad effect; while others have believed that some mineral ingredients, such as calcium carbonate, are useful.

It may be true that water containing a large quantity of organic matter, or much calcium and magnesium sulphate, has been used for long periods without any ill effects. The water of the Canal de l'Ourcq, which contains much calcium bicarbonate, and some calcium and magnesium sulphate, was found by Parent-Duchâtelet to produce no bad effect, and Boudet has lately asserted the same thing.*

In some of these cases, however, very little careful inquiry has been made into the state of health of those using the water, and that most fallacious of all evidence, a general impression, without a careful collection of facts, has often been the only ground on which the opinion has been come to. As well observed by Mr Simon, in one of his philosophical Reports,† we cannot expect to find the effect of impure water always sudden and violent; its results are indeed often gradual, and may elude ordinary observation, yet be not the less real and appreciable by a close inquiry. In fact, it is only when striking and violent effects are produced that public attention is arrested; the minor and more insidious, but not less certain, evils are borne with the indifference and apathy of custom. In some cases it is by no means improbable that the use of the impure water, which is supposed to be innocuous, has been really restricted, or that experience has shown the necessity of purification in some way. This much seems to be certain, that as precise investigations proceed, and, indeed, in proportion to the care of the inquiry and the accuracy of the examination, a continually increasing class of cases is found to be connected with the use of impure water, and it seems only reasonable to infer that a still more rigid inquiry will further prove the frequency and importance of this mode of origin of some diseases.

Animal organic matter, especially when of fæcal origin; vegetable organic matter, when derived from marshes; and some salts, are the principal noxious ingredients.

Of the hurtful substances, the suspended animal, and especially fæcal matters, are probably the worst. At least, it is remarkable how frequently, both in outbreaks of diarrhœa and typhoid fever, the reports notice turbidity, discoloration, and smell of the water. It is this fact which makes the examina tion of colour and turbidity so important. The thoroughly dissolved organic matters appear less hurtful; at least there is some evidence that perfectly clear waters, though containing much matter dissipated by heat, and consisting of dissolved organic matter or its derivatives, are often taken without injury. Probably, also, the more recent the fæcal contamination, the more injurious, since the most poisonous attacks on record have been in cases of wells into which, after slow percolation for some time, a sudden gush of sewage water has taken place.

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* The Canal de l'Ourcq (which has a boat population of about 40,000) is now abandoned as a source of drinking water, and the greater part of Paris is supplied from the river Vanne.

† Second Annual Report to the City of London, p. 121.

It has been frequently stated that the readily oxidisable organic matters in water are the most dangerous. This opinion has probably arisen from the idea that a substance in rapid chemical change is more likely to excite some corresponding and hurtful action in the body; and it may be true, but there is no evidence, to my knowledge, which can be trusted on the point. There is, on the other hand, some evidence that animal matters forming fatty acids give rise to salts which, though not oxidising into nitrous and nitric acid, are as hurtful as the more oxidisable substances.

Of late years, too, an opinion has been expressed that the amount of the mineral substances is of little consequence. This can be true only in a limited sense; there are some mineral substances, such as sodium chloride,* or carbonate, or calcium carbonate, which, within certain limits, appear to do no harm. But in the case of other minerals, such as calcium and magnesium sulphates and chlorides, and calcium nitrate, there can be little doubt that their use is injurious to many persons. It seems also probable that a combination of impurities, and especially the co-existence of organic matter and calcium sulphate, is hurtful; at least the analysis of waters which have decidedly produced injury often shows that the impurities have been numerous.

As far as at present known, the existence of infusoria of different kinds is not hurtful, though they may indicate by their abundance the presence of organic impurity. The effect of microzymes, algæ, or fungi, in drinking water is also a matter of which little or nothing is known, though it is very probable that future research may bring out something important in this direction.

The most practical way of stating the facts connected with the production of disease by water will be to enumerate the diseases which have been traced to the use of impure water, and to state the nature of the impurities.

### 1. AFFECTIONS OF THE ALIMENTARY MUCOUS MEMBRANE.

It is reasonable to suppose that the impurities of water would be likely to produce their greatest effect upon the membrane with which they come first in contact. This is in fact found to be the case.

### *Affections of the Stomach—Dyspepsia.*

Symptoms which may be referred to the convenient term dyspepsia, and which consist in some loss of appetite, vague uneasiness or actual pain at the epigastrium, and slight nausea and constipation, with occasional diarrhœa, are caused by water containing a large quantity of calcium sulphate and chloride, and the magnesian salts. Dr Sutherland found the hard water of the red sandstone rocks, which was formerly much used in Liverpool, to have a decided effect in producing constipation, lessening the secretions, and causing visceral obstructions; and in Glasgow, the substitution of soft for hard water lessened, according to Dr Leech, the prevalence of dyspeptic complaints. It is a well-known fact that grooms object to give hard water to their horses, on the ground that it makes the coat staring and rough—a result which has been attributed to some derangement of digestion. The exact amount which will produce these symptoms has not been determined, but water containing more than 8 grains of each substance individually or collectively appears to be injurious to many persons. This would correspond to about 10 degrees of permanent hardness. A much less degree than this will affect some persons. In a well water at Chatham, which was found to disagree with so many persons that no one would use the water, the main ingredients were 19 grains of carbonate of lime, 11 grains of calcium sulphate, and 13 grains of sodium chloride, per gallon. The total solids were 50 grains per gallon. In another case of the same kind, the total solids were 58 grains per gallon, the calcium carbonate was 22, the calcium sulphate 11, and the sodium chloride 14 grains per gallon.

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* Wanklyn has actually proposed to add sodium chloride to drinking water, to the extent of 50 grains per gallon, in order to improve its taste.

Iron, in quantities sufficient to give a slight chalybeate taste, often produces slight dyspepsia, headache, and general malaise. Custom seems to partly remove these effects.

### *Diarrhœa.*

Many conditions produce diarrhœa.

(*a*) *Suspended Mineral Substances.*—Clay, marl—as in the cases of the water of the Maas, the Mississippi, the Missouri, Rio Grande, Kansas,[*] of the Ganges, and many other rivers—will at certain times of the year produce diarrhœa, especially in persons unaccustomed to the water. The hill diarrhœa at Dhurmsala is produced, apparently, by suspended very fine scales of mica.[†]

(*b*) *Suspended Animal, and especially Fœcal Matters*, have produced diarrhœa in many cases; such water always contains dissolved organic matters, to which the effect may be partly owing. The case of Croydon in 1854 (Carpenter) is one of the most striking on record. In cases in which the water is largely contaminated with suspended sewage, it is important to observe that the symptoms are often markedly choleraic (purging, vomiting, cramps, and even some loss of heat). This point has been again noticed by Oldekop of Astrachan,[‡] who found marked choleraic symptoms to be produced by the water of the Volga, which is impregnated with sewage. Seven cases in one house of violent gastro-intestinal derangement (vomiting, diarrhœa, colic, and fever), produced by water contaminated by sewage which had passed into the cistern, are recorded by Dr Gibb.[§] In the prison at Halle an outbreak of diarrhœa was traced by Dolbruck to the contamination of water with putrid substances. In St Petersburg the water of the Neva, which is rich in organic substances, give diarrhœa to strangers.[‖]

Suspended animal and vegetable substances, washed off the ground by heavy rain into shallow wells, often produced diarrhœa, as at Prague in 1860, when an endemic of "catarrh of the alimentary canal" was produced by heavy floods washing impurities into the wells.[¶]

(*c*) *Suspended Vegetable Substances.*—In this country, and also in the late American civil war, several instances have occurred of diarrhœa arising from the use of surface and ditch water, which ceased when wells were sunk; possibly there might be also animal contamination. It is not, therefore, quite certain that suspended vegetable matter was the *vera causa.* Surgeon-Major Gore has recorded a violent outbreak of diarrhœa at Bulama, on the west coast of Africa,* produced by the water of a well; the water was itself pure, but was milky from suspended matters, consisting of debris of plants, chlorophyll, minute cellular and branched algæ, monads, polygastrica, and minute particles of sand and clay. When filtered the water was quite harmless.

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[*] Hammond's Hygiene, p. 218.

[†] Whitwell, *vide* Dr Macnamara's 8th Report on Potable Waters in Bengal, Appendix, p. 44.

[‡] Virchow's Archiv, band xxvi. p. 117.

[§] British Medical Journal, Oct. 1870.

[‖] Ilisch, quoted by Roth and Lex, Mil. Gesundheitspfl., p. 24.

[¶] Canstatt's Jahresb. 1862, vol. ii. p. 31.

(*d*) *Dissolved Animal Organic Matter.*—The opinion is very widely diffused that dissolved and putrescent animal organic matter, to the amount of 3 to 10 grains per gallon, may produce diarrhœa. This is possibly correct, but two points must be conceded—*1st,* That there are usually other impurities which aid the action of the organic matter; and *2d,* That organic matter, even to the amount of 10 to 15 grains per gallon, may exist without bad effects, if it be perfectly dissolved. In the latter case the water is, however, always clear and sparkling, never tainted or discoloured. The frequent presence of other impurities renders it difficult to assign its exact influence to dissolved organic matters.

In the case of a well-ventilated court in Coventry,† where diarrhœa was constantly present, the water contained 5·68 grains per gallon of volatile and combustible matter, but then it contained also no less than 105 grains of fixed salts, which, as the water had a permanent hardness of 51°·6 (Clark's scale) after boiling, must have consisted of calcium and magnesium sulphates and chlorides. It also contained alkaline salts, nitrates, and ammonia. The composition was therefore so complex, that it is difficult to assign to the organic matter its share in the effects.

The animal organic matter derived from graveyards appears to be especially hurtful; here also ammonium and calcium nitrites may be present.

(*e*) *Dissolved Vegetable Matter.*—There is no evidence at present to show that this produces diarrhœa.

(*f*) *Fœtid Gases.*—Water containing much sulphuretted hydrogen will give rise to diarrhœa, especially if organic matter be also present. In the late Mexican War (1861–62), the French troops suffered at Orizaba from a peculiar dyspepsia and diarrhœa, attended with immense disengagement of gas and enormous eructations after meals. The eructed gas had a strong smell of sulphuretted hydrogen.‡ This was traced to the use of water from sulphurous and alkaline springs; even the best waters of Orizaba contained organic matter and ammonia in some quantity. The experiments of Professor Weber have shown what marked effects are produced by the injection of sulphuretted hydrogen in solution in water into the blood; is it possible that water containing animal organic matter may occasionally form $SH_2$ after absorption into the blood, and that the poisonous effect of some water may be owing to this? The symptoms of poisoning by water contaminated by sewage are sometimes very like those noted by Weber in his experiments, viz., diarrhœa and even choleraic symptoms (lowering of temperature), and irritation of the lungs, spine, liver, and kidneys.

The absorption of sewer gases, as when the overflow-pipe of a cistern opens into the sewers, will cause diarrhœa. This seems perfectly proved by the case recorded by Dr Greenhow, in Mr Simon's second report.§

(*g*) *Dissolved Mineral Matters,* if passing a certain point, produce diarrhœa.

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* Report on Hygiene by the Author, "Army Medical Report," vol. v. p. 428.

† Greenhow, in Second Report of the Medical Officer of the Privy Council, 1860, p. 75.

‡ Poncet, in Rec. de Mem. de Med. Mil. 1863, p. 218. The exact words are "une odeur d'acid sulfurique," but "sulfhydrique" must be meant.

§ Second Report of the Medical Officer of the Privy Council, Parl. Paper, 1860, p. 153.

Boudin refers to an outbreak of diarrhœa at Oran, in Algiers, which was distinctly traced to bad water, and ceased on the cause being removed; the composition of the water is not explicitly given, but it contained lime, magnesia, and carbonate of soda. Sulphates of lime and magnesia also cause diarrhœa, following sometimes constipation. The selenitic well waters of Paris used to have this effect on strangers. Parent-Duchâtelet[*] noticed the constant excess of patients furnished by the prison of St Lazare, in consequence of diarrhœa, and he traced this to the water, which "contained a very large proportion of sulphate of lime and other purgative salts;" and he tells us that Pinel had *noticed the same fact twenty years before in a particular section of the Salpêtrière. In some of the West Indian stations, the water drawn from the calcareous formation has been long abandoned, in consequence of the tendency to diarrhœa which it caused.*

*Nitrate of lime* waters also produces *diarrhœa. A case is on record,* in which a well water was obliged to be disused, in consequence of its impregnation with butyrate of lime (105 grains per gallon), which was derived from a trench filled with decomposing animal and vegetable matters.[†]

Brackish water (whether rendered so by the sea, or derived from loose sands) produces diarrhœa in a large percentage of persons, and at some of the Cape frontier stations water of this character formerly caused much disease of this kind. In a water I examined, which became brackish from sea water, and which produced diarrhœa in almost all persons, I found the amount of chloride of sodium to be 253 grains per gallon. But, doubtless, a much less quantity than this, especially if chloride of magnesium be present, will act in this way.

(*h*) *Metallic Impregnation.*—Occasionally animal organic matter acts in an indirect way, by producing nitrites and nitrates, which act on metals.

Dr Bædeker,[‡] a physican in Witten, was called to some cases of sickness produced apparently by water. On examining the point, he found the water was drawn from a pump with a copper cylinder, and contained a considerable quantity of copper, which seemed to be in combination with some organic matter.[§]

Lead (as might have been anticipated) was also largely present in this water, as leaden pumps were used; iron, on the contrary, was not dissolved.

### *Dysentery.*

Dysentery also is decidedly produced by impure water, and this cause ranks high in the etiology of dysentery, though perhaps it is not the first.

Several of the older army-surgeons refer to this cause. Pringle does so several times, and Donald Munro, in the "Campaigns in Flanders and Germany." In the West Indies, Lemprière,[||] in 1799, noticed the increase of bowel complaints in Jamaica in May, when, after floods, the water was bad and turbid, "and loaded with dirt and filth." He also mentions, that at Kingston and Port Royal the dysentery was owing to brackish water. It was not, however, for many years after this that fresh sources of water were sought for in the West Indies, and that rain water began to be used when good spring or river water could not be got.

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[*] Hygiène Publique, t. i. p. 236.

[†] Zeitschrift fur Hygiene, vol. i. p. 166. See also a remark on the effect of calcium and potassium nitrate in causing a tendency to diarrhœa in the Report on the Drainage of Berlin (Die Kanalisation von Berlin, 1868, pp. 27, 28).

[‡] Pappenheim's Beitrage, heft iv. p. 49.

[§] The amount of copper required to produce poisonous symptoms appears to be doubtful. It is said that the miners in the desert of Attacama, in South America, prefer to use water containing so much copper as to have a distinct green colour, rather than the water brought up from the wells near the shore in skins, which give it an unpleasant taste. It is true that it is used for making coffee and may thus be to a certain extent purified.

[||] Vol. i. p. 25.

Davis[*] mentions as a curious fact, in reference to the West Indies, that ships' crews, when ordered to Tortola, were "invariably seized with fluxes," which were caused by the water. But the inhabitants who used tank (*i.e.*, rain) water were free; and so well known was this, that when any resident at Tortola was invited to dinner on board a man-of-war, it was no unusual thing for him to carry his drinking water with him.

The dysentery at Walcheren, in 1809, was in no small degree owing to the bad water, which was almost everywhere brackish.

*The epidemic at Guadaloupe, in 1847, recorded by Cornuel, seems also quite conclusive as to the effect of impure water in causing, not merely isolated cases, but a wide-spread outbreak.*[†]

In 1860, at Prague, there were many cases of dysentery, clearly traced to the use of water of wells and springs rendered foul by substances washed into the water by heavy floods. Exact analyses were not made.

On the West Coast of Africa (Cape Coast Castle), an attack of dysentery was traced by Surgeon-Major Oakes to the passage of sewage from a cesspool into one of the tanks. "This was remedied, and the result was the almost total disappearance of the disease."

That in the East Indies a great deal of dysentery has been produced by impure water, is a matter too familiar almost to be mentioned (Annesley; Twining). Its constant prevalence at Secunderabad, in the Deccan, appears to have been partly owing to the water which percolated through a large grave-yard. One of the sources of water contained 119 grains of solids per gallon, and in some instances there were 8, 11, and even 30 grains per gallon of organic matter. (Indian Report, p. 44.)

Champouillon[‡] has lately recorded a case in which two regiments used the impure water from the Canal de l'Ourcq, near Paris. One regiment mixed the water with coffee or red wine, the tannin of which united with the organic matter ; this regiment had no dysentery. The second regiment used brandy, which precipitated the organic matter on the side of the vessel, where it putrified. This regiment suffered from dysentery; the substitution of red wine for brandy stopped the disease.

The great effect produced by the impure water of Calcutta in this way has been pointed out by Chevers. (Indian Annals, No. 17, p. 70, 1864.)

In time of war this cause has often been present; and the great loss by dysentery in the Peninsula, at Ciudad Rodrigo, was partly attributed by Sir J. M'Grigor to the use of water passing through a cemetery where nearly 20,000 bodies had been hastily interred.

The impurities which thus produce dysentery appear to be of the same kind as those which cause the allied condition, diarrhœa. Suspended earthy matters, suspended animal organic matter, calcium and magnesium sulphates and chlorides, calcium and ammonium nitrates, large quantities of sodium and magnesium chlorides in solution, appear to be the usual ingredients ; but there are few perfect analyses yet known.[§]

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[*] On the Walcheren Fever, p. 10.

[†] See a review by the author on Dysentery, in the "British and Foreign Medical and Chirurgical Review" for 1847, for fuller details of this epidemic.

[‡] Rec. de Mem. de Med. Mil. 1872, Sept. p. 230.

[§] A localised epidemic of dysentery occurred in some barracks at Nurnberg in the summer of 1872, 30 cases and 4 deaths taking place among the soldiers. The absorption of putrefaction gases from the cloaca in the wings of the building by the drinking water, was considered to be the cause ; the water contained nitrates and free ammonia. An individual predisposition

The observations which prove so satisfactorily that the dysenteric stools can propagate the disease, make it probable that, as in the case of typhoid fever and cholera, the accidental passage of dysenteric evacuations into drinking water may have some share in spreading the disease.

### 2. AFFECTION OF OTHER MUCOUS MEMBRANES BESIDES THE ALIMENTARY.

Little has yet been done to trace out this point. At Prague, after the severe flood of 1860, bronchial catarrh was frequent, probably caused chiefly by the chills arising from the great evaporation; but it was noticed that bronchial catarrh was most common when the drinking water was foulest and produced dysentery. Possibly the bronchial and the urinary mucous membranes may also suffer from foul water; the point is well worthy of close investigation.

### 3. SPECIFIC DISEASES.

That some of the specific diseases are disseminated by drinking water is a fact which has only attracted its due share of attention of late years. It is certainly one of the most important steps in etiology which has been made in this century, and the chief merit of its discovery is owing to the late Dr Snow.

#### *Malarious Fevers.*

Hippocrates states that the spleens of those who drink the water of marshes become enlarged and hard; and Rhazes not only asserted this, but affirmed that it generated fevers. Little attention seems to have been paid to this remark, and in modern times the opinions of Lancisi, that the air of marshes is the sole cause of intermittents, has been so generally adopted, that the possibility of the introduction of the cause by means of water, as well as of air, was overlooked. Still, it has been a very general belief among the inhabitants of marshy countries, that the water could produce fever. Henry Marshall* says that the Singhalese attribute fevers to impure water, "especially if elephants or buffaloes have been washing in it," and it is to be presumed that he referred to periodical fevers. On making some inquiries of the inhabitants of the highly malarious plains of Troy, during the Crimean war, I found the villagers universally stated, that those who drank marsh water had fever at all times of the year, while those who drank pure water only got ague during the late summer and autumnal months. The same belief is prevalent in the south of India; and in Western Candeish, Canara, Balaghut, and Mysore, and in the deadly Wynaad district, it is stated by Mr Bettington of the Madras Civil Service, that it "is notorious that the water produces fever and affections of the spleen." The essay by this gentleman† gives, indeed, some extremely strong evidence on this point. He refers to villages placed under the same conditions as to marsh air, but in some of which fevers are prevalent, in others not; the only difference is, that the latter are supplied with pure water, the former with marsh or nullah water full of vegetable debris. In one village there two sources of supply,—a tank fed by surface and marsh water and a spring; those only who drink the tank water get fever. In a village (Tulliwaree) no one used to escape the fever; Mr Bettington dug a well, the fever disappeared, and, during fourteen years, has not returned.

Another village (Tambatz) was also "notoriously unhealthy," a well was

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to the disease appeared, however, to be also necessary. (Schmidt's Jahrbücher, 1874. 1 vol. p. 25.)

* Topography of Ceylon, p. 52.

† Indian Annals, 1856, p. 526.

dug, and the inhabitants became healthy. Nothing can well be stronger than the positive and negative evidence brought forward in this paper.

Dr Moore (Indian Annals, 1867) has also noted his opinion of malarious disease being thus produced; and M. Commaille has since (Rec. de Mém. de Méd. Mil., Nov. 1868, p. 427) stated, that in Marseilles paroxysmal fevers, formerly unknown, have made their appearance, since the supply to the city has been taken from the canal of Marseilles. In reference also to this point, I observe that Dr Townsend, the Sanitary Commissioner for the Central Provinces in India, mentions in one of his able reports (for 1870, published at Nagpore in 1871, para. 143, *et. seq.*) that the natives have a current opinion that the use of river and tank water in the rainy season (when the water always contains much vegetable matter) will almost certainly produce fever (*i.e.*, ague), and he believes there are many circumstances supporting this view. In this way the prevalence of ague in dry elevated spots is often, he thinks, to be explained. He mentions also that the people who use the water of streams draining forest lands and rice fields "suffer more severely from fever (ague) than the inhabitants of the open plain drawing their water from a soil on which wheat grows. In the former case there is far more vegetable matter in the water. The Upper Godavery tract is said to be the most aguish in the province, yet there is not an acre of marshy ground; the people use the water of the Godavery, which drains more dense forest land than any river in India.

In the "Landes" (of south-west France), the water from the extensive sandy plain contains much vegetable matter, obtained from the vegetable deposit, which binds together the siliceous particles of the subsoil. It has a marshy smell, and, according to Fauré, produces intermittents and visceral engorgements. Dr Blanc, in his papers on Abyssinia, mentions that on the march from Massowah to the highlands, Mr Prideaux and himself, who drank water only in the form of tea or coffee, entirely escaped fever, while the others who were less careful suffered, and, as Dr Blanc believes, from the water.

The same facts have been noticed in this country. Twenty years ago Mr Blower of Bedford mentioned a case in which the ague of a village had been much lessened by digging wells, and he refers to an instance in which, in the parish of Houghton, almost the only family which escaped ague at one time was that of a farmer who used well water, while all the other persons drank ditch water.*

At Sheerness the use of the ditch water, which is highly impure with vegetable debris, has been also considered to be one of the chief causes of the extraordinary insalubrity.†

At Versailles a sudden attack of ague in a regiment of cavalry was traced to the use of surface water taken from a marshy district.‡

The case of the Argo, recorded by Boudin,§ is an extremely strong one. In 1834, 800 soldiers in good health embarked in three vessels to pass from Bona in Algiers to Marseilles. They all arrived at Marseilles the same day. In two vessels there were 680 men without a single sick man. In the third vessel, the Argo, there had been 120 men; thirteen died during the short passage (time not given), and of the 107 survivors no less than 98 were dis-embarked with all forms of paludal fevers, and as Boudin himself saw the men, there was no doubt of the diagnosis. The crew of the Argo had not a single sick man.

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* Snow "On the Mode of Communication of Cholera," 2d edit. 1855, p. 130.

† Is it not possible that the great decline of agues in England is partly due to a purer drinking water being now used? Formerly, there can be little doubt, when there was no organised supply, and much fewer wells existed, the people must have taken their supply from surface collections, and ditches, as they do now, or did till lately, at Sheerness.

‡ Grainger's Report on Cholera. Appendix (B), page 95; footnote.

§ Traité de Géographie et de Statistique Médicales, 1857, t. i. p. 142.

All the soldiers had been exposed to the same influences of atmosphere before embarkation. The crew and the soldiers of the Argo were exposed to the same atmospheric condition during the voyage; the influence of air seems therefore excluded. There is no notice of the food, but the production of malarious fever from food has never been suggested. The water was, however, different—in the two healthy ships the water was good. The soldiers on board the Argo had been supplied with water from a marsh, which had a disagreeable taste and odour; the crew of the Argo had pure water. The evidence seems here as nearly complete as could be wished.*

One very important circumstance is the rapidity of development of the malarious disease and its fatality when introduced in water. It is the same thing as in the case of diarrhœa and dysentery. Either the fever-making cause must be in larger quantity in the water, or, what is equally probable, must be more readily taken up into the circulation and carried to the spleen, than when the cause enters by the lungs.

In opposition, however, to all these statements must be placed a remark of Finke's† that in Hungary and Holland marsh water is daily taken without injury. But in Hungary, Dr Grosz states that, to avoid the injurious effects of the marsh water, it is customary to mix brandy with it, "a custom which favours hypertrophies of the inner organs." ‡ Professor Colin, of the Val de Grâce, who is so well known for his researches on intermittent fever,§ is also inclined to question the production of paroxysmal fevers by marsh water. He cites numerous cases in Algiers and Italy, where impure marsh water gave rise to indigestion, diarrhœa, and dysentery, but in no case to intermittent fever, and in all his observations he has never met with an instance of such an origin of ague. He therefore denies this power, and in reference to the celebrated case of the Argo, without venturing to contest it, he yet views it with suspicion, and questions whether Boudin has given the exact details.

An instructive case, however, is recorded by Surgeon-major Faught (Army Medical Reports, vol. xvii. p. 212). The artillery quartered at Tilbury Fort (in the Gravesend district) have generally suffered more or less from ague, whilst the people at the railway station, and the coastguard and their families in the ship lying just outside the fort, never suffer from malarious poisoning. The troops have been supplied with drinking water from two underground tanks which receive rain-water from the roof of the barracks, whilst the other persons above mentioned draw their drinking-water from a spring near the railway station. From December 1873 to July 1874 the troops were supplied from the same source, on account of the barrack tanks being out of repair. The following table shows the returns of sickness :—

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* Ritter, Hirsch in Jahresb. für gen. Med. for 1869, p. 192.

† Oesterlen's Handb. der Hygiene. 2d edit. 1857, p. 129; footnote.

‡ Quoted by Wutzur, Reise in den Orient. Europas, band i. p. 101.

§ De l'Ingestion des eaux Marécageuses comme cause de la Dysentérie et des Fièvres Intermittentes, par L. Colin, Paris 1872.

| Date. | Strength. | Admissions for Ague. | Percentage of Admissions. | Ratio of Admissions per annum. | Water used. | |
|---|---|---|---|---|---|---|
| 1872.<br>Jan. to June. | 103 | 34 | 33 | 66 | Water from barrack tanks. | The analyses of the waters showed that the tanks were exposed to soakage from the surrounding salt marsh, for the so-called rain-water yielded 41·3 grains per gallon of total solids in the one case, and 145·25 in the other, the chlorine being respectively 12·8 and 33·9. The station water gave 38 grains total solids and only 3·5 of chlorine. As regards organic matter, the tank waters showed actually less impurity than the station water by the ammonia method, but by the permanganate method they were three times as impure. For full details and for the microscopic examination, see the original paper. |
| 1873.<br>Jan. to June. | 102 | 12 | 11·8 | 23·6 | Do. | |
| 1873–4.<br>Dec. 1873 to July 1874. | 90 | 1* | 1·1 | 1·9 | Water from spring at the railway station. | |
| 1874–5.<br>Nov. 1874 to March 1875. | 53 | 4† | 7·6 | 22·8 | Water from barrack tanks. | |

* This case was in hospital only five days: it occurred only a few days after the arrival of the battery.

† None of these had ever had ague before; two had to be sent on furlough, being much debilitated by malaria.

### *Typhoid Fever.*

The belief that typhoid fever can spread by means of water as well as air appears to be quite of modern origin, though some epidemics, such as the "Schleim-fieber" of Göttingen in 1760, were attributed in part to the use of impure water. In 1822, Walz affirmed that an outbreak of "typhus" (typhoid) at Saarlouis, in Rhenish Prussia, was caused by impure water; and in 1843, Müller discovered that 129 cases of typhus abdominalis (typhoid), and 21 deaths, which occurred in the garrison at Mayence, were produced by fæcal matter passing into the drinking water, which had a disagreeable, putrid smell. In 1848, E. A. W. Richter published an account of an outbreak of the same kind which occurred in a school at Vienna, from the contents of a sewer passing into the drinking water.* In 1852, Dr Austin Flint† published the particulars of a similar outbreak of typhoid fever at the hamlet of North Boston (Erie, U.S.) in 1843.

In 1852–53, a severe outbreak of typhoid fever took place at Croydon, and was thoroughly investigated by many competent observers; and it was shown by Dr Carpenter of Croydon that it was partly, at any rate, spread by the pollution of the drinking water from the contents of cesspools.

In 1856, Dr Routh‡ published a case in which the evacuations of a typhoid patient were thrown into a closet, the pipe of which passed directly into the cistern of the drinking water, in a well-ventilated house at Hastings. No less than eight persons were affected with more or less typhoidal symptoms; many of these had not been brought into any personal contact with the sick person.

In 1859, Dr W. Budd§ published two very conclusive cases, in which well water was contaminated by sewage.

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* All these cases are related by Riecke in his excellent work "Der Kreigs und Friedens-Typhus." Nordhausen, 1850, pp. 44-58.

† Clinical Reports on Continued Fever. By Austin Flint, M.D. Buffalo, 1852, p. 380.

‡ Fæcal Fermentation as a Cause of Disease. Pamphlet. Lond. 1056, p. 34.

§ Lancet, Oct. 29, 1859, p. 432.

There is no satisfactory evidence that typhoid stools had been in the sewage matter, but their presence is not excluded. I learn, from personal communication with Dr Budd, that he has long been convinced of the *occasional* propagation of typhoid fever in this way.

In 1860, an outbreak of typhoid fever occurred at the Convent of Sisters of Charity at Munich. 31 persons out of 120 were attacked between the 15th September and the 4th of October, with severe illness, and 14 of these cases were true typhoid; 4 died. The cause was traced to wells impregnated with much organic matter (and among other things typhoid dejections), and containing nitrates and lime. On the cessation of the use of this water, the fever ceased.[*]

The propagation of typhoid fever in Bedford would certainly appear, from Mr Simon's report,[†] to have been partly through the medium of the water.

Dr Schmitt [‡] has for several years paid particular attention to this point, and in 1861 published several very striking cases.

A case bearing on the same point was brought before the Metropolitan Officers of Health in 1862,[§] by Mr Wilkinson of Sydenham. In this case the water was contaminated by absorption of sewer gases.

In 1862, a very sudden and severe outbreak of typhoid in a barrack at Munich was traced to water impregnated with fæcal matter; on ceasing to use the water, the disease disappeared.[‖] In 1865 a very remarkable outbreak of typhoid occurred at Ratho, in Scotland, and was traced to drinking water contaminated with sewage.[¶] In 1866 typhoid fever broke out in a girls' school at Bishopstoke, near Southampton, and was traced unequivocally to the bursting of a sewer pipe into the well. The water was disagreeable both to smell and taste. 17 or 18 persons were affected out of 26 or 28. Several very striking instances are recorded in Mr Simon's Reports by Drs Seaton, Buchanan, and Thorne,[**] and in some of these cases analyses of the water were made, which showed it to be impure, and to contain organic sewage, or its derivatives. A very good case, at the Garnkirk works in Glasgow, is recorded by Dr Perry.[††] Dr De Renzy, the Sanitary Commissioner of the Punjab, has also published a remarkable paper on the extinction of typhoid fever in Millbank prison, and shows, from the statistics of many years, that the fever has entirely disappeared since the use of Thames water was given up; the disappearance was coincident with the change in the water supply. Two excellent cases are recorded by Dr Clifford Allbutt[*] and one by Dr Wohlrab, which are free from ambiguity.[†] A very good case is recorded by Dr Latham.[‡] Typhoid was introduced into a village and spread by the agency of contaminated drinking water.[§]

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[*] Edinburgh Medical Journal, Jan. 1862, p. 1153. See also Gietl, Die Ursachen des Enter. Typhus in München, 1865, p. 58.

[†] Third Report of the Medical Officer of the Privy Council, 1860.

[‡] Journ. de Med. de Bruxelles, Sept. 1861; and Canstatt's Jahresb. for 1861, band iv. pp. 182, 183. See the 2d edition of this work for a short account of them.

[§] British Medical Journal, March 1, 1862.

[‖] Gietl, Die Ursachen des Ent. Typhus in München, 1865, p. 62. In this little book is much evidence to show the propagation of typhoid by foul water and by deficient arrangements for removal of excreta, as well as many instances of the carrying of the disease from place to place, analogous to those narrated by Bretonneau many years ago.

[¶] Edin. Med. Journ. Dec. 1865. In this case a groom came to the house ill with typhoid from Dundee, and thus introduced the disease. This fact was communicated to me by a relation of the owner of the house,

[**] Dr Seaton's Report on Tottenham (Report of Medical Officer to the Privy Council for 1866, p. 215). Dr Buchanan on Guildford (Ibid. for 1867, p. 34); Dr Thorne's Report on Terling (Ibid. p. 41); Dr. Buchanan's Report on Wicken-Bonant (12th Report, p. 72). In all these instances the evidence reaches the highest degree of probability, and in the cases of Guildford and Wicken-Bonant of almost absolute certainty. See also Report on Sherborne by Dr Blaxall; on Caius College, Cambridge, by Dr Buchanan (both in No. ii. new series); on Lewes by Dr Thorne (No. iv. new series); also the case of Over-Darwen (Sanitary Record, 1875); case given by Dr Stallard (Lancet, Feb. 1872); Dr Barclay's Reports on Bangalore (Army Med. Reports, vol. xiii. p. 208). Geissler also quotes from Hägler a very strong case occurring at Lausen. Schmidt's Jahrb. 1874, No. 2, p. 185).

[††] Lancet, June 1868.

That water may be the medium of propagating typhoid thus seems to be proved by sufficient evidence; and it has been admitted by men who have paid special attention to this subject, as Jenner, W. Budd, and Simon. It does not seem unlikely, indeed, that this mode of spreading will be found to be far more common than is supposed.[||]

Two questions arise in connection with this subject—

1. As typhoid fever undoubtedly spreads also through the air, What is the proportion of cases disseminated by water, as compared with those disseminated by air? No answer can yet be given to this question.[¶]

There is one point of some interest. When the dates of attack are given, it is curious to observe how short the incubative period appears to be; while it is probable that it takes many days (8 to 14) after the typhoid poison has entered with the air before the early malaise comes on, in some of the cases of typhoid brought on by water, two or three days only elapse before the symptoms are marked.[**]

A very large number also of the susceptible persons who drink the water are affected.

2. Will decomposing sewage in water produce typhoid fever, or must the evacuations of a typhoid patient pass in? This is part of the larger question of the origin and propagation of specific poisons. It is certainly remarkable, in the range of cases recorded by Schmitt, how uniformly the possibility of the passage of typhoid stools is disregarded. Everything is attributed to fæcal matters merely. A case recorded by Dr Downes,[††] in which six cases of typhoid resulted from the overflow of non-typhoid sewage into a well, supports this view. On the other hand, in the cases recorded by Allbutt and Wohlrab already referred to, contaminated water had been used for some time without producing typhoid fever. Persons affected with typhoid enteric fever then entering the place, their discharges passed into the drinking water, and then an outbreak of typhoid followed. An extremely strong case is given by Ballard.[‡‡] Very polluted water had been used for years by the inhabitants of the village of Nunney without causing fever, when a person with enteric fever came from a distance to the village, and the excreta from this person

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[*] See my Report on Hygiene, Army Med. Dept. Blue Book, 1860. p. 23.

[†] Archiv. der Heilk. vol. xii. p. 134 (1871).

[‡] Lancet, July 15, 1871.

[§] A remarkable case is reported by Dr Zuckschwerdt occurring in the orphan asylum at Halle in 1871. Also by Dr Burkart at Stuttgart, at Reinhartsdorf in Switzerland and at Schandau, all distinctly traceable to impure water. (Schmidt's "Jahrbücher" 1874.)

[||] Biermer from an analysis of 1300 cases cites evidence of water carriage (Schmidt's Jahrb. 1873, No. 8, p. 195).

[¶] Mr Simon in his 2d Report, new series, gives a table of 146 outbreaks investigated by his officers in 1870-3 (4 years), in all of which great excremental pollution of air or water, or generally of both, was found.

[**] Dr. W Budd says, in a letter to me—"In the cases in which the poison is conveyed by water, infection seems to be much more certain; and I have reason to think that the period of incubation is materially shortened. An illustration of this seems to be furnished by the memorable outbreak which occured at Cowbridge some years ago, and which presented this unexampled fact: that out of some 90 or 100 persons who went to a race ball at the principal inn there, more than one-third were within a short time laid up with fever. In this case there was satisfactory reason to think that the water was contaminated, though there was no chemical examination." In the attack at Guildford, however, the incubative period was not shortened, as Dr Buchanan calculates it at 11 days.

[††] Lancet, 27th April, 1872.

[‡‡] Report to the Local Government Board on an outbreak of enteric fever at Nunney, Sept. 1872

*were washed into the stream supplying the village. Between June and October 1872, no less than 76 cases occurred out of a population of 832 persons. All those attacked drank the stream water habitually or occasionally.* All who used filtered rain or well water escaped, except one family who used the water of a well only 4 or 5 yards from the brook. The case seems quite clear—first, that the water caused the disease; and secondly, that though polluted with excrement for years, no enteric fever appeared until an imported case introduced the virus. Positive evidence of this kind seems conclusive, and I think we may now safely believe that the presence of typhoid evacuations in the water is necessary. Common fæcal matter may produce diarrhœa, which may perhaps be febrile,* but for the production of enteric fever the specific agent must be present. The opinion that the stools of typhoid are the especial carriers of the poison was first, I believe, explicitly stated by Canstatt,† and has been also ably argued by W. Budd.

### *Cholera.*

Few of the earlier investigators of cholera appear to have imagined that the specific poison might find entrance by the means of drinking water. There is an intimation of the kind in a remark by Dr Muller:‡ and Jameson, in the Bengal Report of 1820, alludes to the effect of impure water, but in a cursory way.

In 1849 the late Dr Snow, in investigating some circumscribed outbreaks of cholera in Horsleydown, Wandsworth, and other places, came to the conclusion that, in these instances, the disease arose from cholera evacuations finding their way into the drinking water. Judging from the light of subsequent experience, it now seems extremely probable that this was the case, and to Dr Snow must certainly be attributed the very great merit of discovering this most important fact. At first, certainly, the evidence was defective,§ but gradually fresh instances were collected, and in 1854 occurred the celebrated instance of the Broad Street pump in London, which was investigated by a committee, whose report, drawn up by Mr John Marshall, of University College, with great logical power, contains the most convincing evidence that, in that instance, at any rate, the poison of cholera found its way into the body through the drinking water.‖

In 1855 Dr Snow published a second edition of his book, giving an

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* A good instance is given by Mr R. Bond-Moore (London Medical Record, May 27, 1874, page 327) as occurring at Sedgley Park school. Two years previously the water supply became contaminated with ordinary sewage, but no typhoid fever resulted, although there was diarrhœa, sickness, great languor, and great prostration. The leaking drain was repaired and the attack ceased. Two years after, typhoid was introduced by one of the boys and spread, apparently by the use of the closets.

† "Wahrscheinlich sind die Exhalationen des Krankes, seine Excremente, *vielleicht die typhösen Aftergebilde im Darme,* die Träger des Contagiums."—Canstatt, *Spec. Path. und Ther.* 2d edit. band ii. p. 572 (1847).

‡ Einige Bemerkungen über die Asiat. Cholera. Hanover, 1848, p. 36.

§ There seemed at once an *a priori* argument adverse to this view, as, at that time, all evidence was against the idea of cholera evacuations being capable of causing the disease. They had been tasted and drunk (in 1832) by men, and been given to animals, without effect. Persons inoculated themselves in dissections constantly, and bathed their hands in the fluids of the intestines; in India the pariahs who remove excreta, and everywhere the washerwomen who washed the clothes of the sick, did not especially suffer. And to these arguments must be added the undoubted fact, that there were serious deficiencies of evidence in Dr Snow's early cases. (See review by the author in the British and Foreign Medical Chirurgical Review, April 1855.)

‖ Report on the Cholera Outbreak in St James's Westminster, in 1854. London, Churchill, 1855. Every point is discussed in this report with a candour and precision which leaves nothing to be desired. For further evidence on this outbreak, see Indian Sanitary Report: evidence of Dr Dundas Thomson, p. 272.

*account of all the cases hitherto known, and adding some evidence also as to the introduction in this way of other specific poisons.*[*]

*The facts, at present, may be briefly summed up as follow:—*

1. Local outbreaks, in which contamination of the drinking water was either proved or in which the evidence of the origin and succession of cases seemed to make it certain that the cause was in the drinking water. In England, Dr Snow and others have thus recorded cases occurring in 1849 and 1854 at Horsleydown, Broad Street, Wandsworth, West Ham, &c. In 1865 the important outbreak at Newcastle-on-Tyne,[†] when all the circumstances pointed very strongly to the influence of the impure Tyne water. In 1865 occurred the remarkable and undoubted case of water poisoning at Theydon Bois, recorded by Mr Radcliffe,[‡] and in the following year the violent outbreak in the East of London was supposed to be connected with the circulation of impure water by the East London Water Works Company. Much discussion has taken place as to the real influence of the impure water which it is admitted on all hands was used. Mr Radcliffe[§] and Dr Farr[‖] have collected the evidence in favour of the opinion that the sudden outburst was really owing to this water; while Dr Letheby and some others have expressed doubts on this point, chiefly on account of the difficulty of reconciling with the hypothesis certain exceptional cases both of immunity and of attack. To me the evidence in favour of the water being the cause appears extremely strong, and far greater difficulty arises if that view is not received than is caused by the exceptional cases referred to, and of which we may not know all the particulars. In the same year (1866) an apparently unequivocal case of production of cholera by the drinking water of a tank on board a steamer occurred at Southampton, and I have recorded the particulars in the Report of the Medical Officer to the Privy Council for 1866.[¶]

A very striking case at Utrecht is noticed by Snellen, and is given by Dr Ballot, of Rotterdam, who has adduced much strong evidence on the influence of the foul water in Holland in spreading cholera.[**]

During the epidemic in 1866, except in the East London case, no such striking instances of local outbreak from water contamination were recorded as in 1849, but there were in some parts, and especially in Scotland, as noticed by Dr Stevenson Macadam,[††] very striking coincidences between the abatement of the disease and the introduction of a fresh and pure supply.

In Germany choleraic water-poisoning has not only been less noticed, but the great authority of Pettenkofer is against its occurrence. At Munich, Pettenkofer[‡‡] could find no evidence whatever in favour of the spread by water; and Günther, in his careful work on Cholera in Saxony,[§§] asserts that no influence whatever was exerted by drinking water. No evidence could be obtained either in Baden or in villages near Vienna.[*] And as in all cases the observers were not only quite competent, but were fully cognizant of the opinions held in England, this negative evidence is of great weight. At the same time, it cannot be allowed to outweigh the English cases, and, moreover, even in Germany some positive evidence has been lately given. Dr Richter[†] attributes a preponderant influence in a local outbreak among the workmen of a sugar-manufactory to the pollution of the drinking water by sewage; and a still more striking case is recorded by Dr Dinger,[‡] in which the discharges of a cholera patient passed into a brook, in which also the clothes were washed; the water of this brook being used for drinking, there was a sudden and very fatal outbreak affecting the persons who took the water.

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[*] On the mode of Communication of Cholera. By John Snow, M.D. London, Churchill, 2d edition, 1855.

[†] For full particulars, see Dr Farr's Report on Cholera in England, 1866, p. 33.

[‡] Report of the Medical Officer to the Privy Council for 1865 (Eighth Report), p. 438.

[§] Report of the Medical Officer to the Privy Council for 1866, p. 266.

[‖] Report on the Cholera Epidemic of 1866 in England. Supplement to the 29th Annual Report of the Registrar-General, 1868.

[¶] Report of Medical Officer to Privy Council for 1866, p. 244. In this case the water was foul tasted, and was certainly contaminated with sewage.

[**] Medical Times and Gazette, May 1869. Thus it was found that those who drank the water of the Polders (reclaimed lands) died at the rate of 17·7 per 1000; those who drank the well-water, 16·8 per 1000; those who drank river-water 11·9 per 1000; those who drank rain-water filtered, only 5·3 per 1000. The city of Amsterdam itself, supplied by an aqueduct with rain-water from the downs near Haarlem had only 4 per 1000. In Rotterdam during the epidemic the mortality fell to one-half immediately on pure water being supplied in the streets. (See paper by J. C. Jaeger.)

[††] Transactions of the Royal Scottish Society of Arts, vol. vii. p. 341 (1867).

[‡‡] Zeitsch, für Biol., band i. p. 353.

[§§] Die Indische Cholera in Sachsen im Jahre. 1865, p. 125.

In India the evidence for cholera water poisoning is at present become very strong. The great cholera outbreak of 1860 and 1861 was attributed by some medical officers to the defilement of the tank water "into which the general ordure of the natives is washed during the rainy season;"[§] and still more recently, what appears to be a striking instance has occurred. No one can read the able account given by Dr Cuningham and Dr Cutliffe in the Bengal Report for 1867[||] of the appearance of cholera among the vast crowd of pilgrims after the great bathing day at Hurdwar, without coming to the conclusion that it was a case of water poisoning on a gigantic scale.[¶]

That in India the cholera poison is often carried by water appears probable, not only from the Hurdwar outbreak, but from the very sudden and violent outbreaks and the great sewage contamination in the water of many districts.[**]

In Central India Dr Townsend has given strong reasons for believing that the cholera of 1868–9 was, to a large extent, dependent on water-fouling. (See Report on Cholera in the Central Provinces.) Dr Macnamara (on Asiatic Cholera, 1870) has given some good evidence on the same side (see pp. 328, *et seq.*), and Dr Cleghorn (*Indian Medical Gazette*, March 1872) has noted some striking proofs of the same fact.[††]

So also in other countries; the attack which caused such losses to the French Division in the Dobrudscha in 1855, when the wells were supposed to be poisoned, and to the English cavalry at Devna,[‡‡] the water was apparently the means of carrying the disease.

In evidence of this kind we must remember that each successive instance adds more and more weight to the instances previously observed, until, from the mere accumulation of cases, the cogency of the argument becomes irresistible.

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[*] Volz and Witlacil, quoted by Hirsch in Jahresb. der gen. Med. for 1867, band ii. p. 221.

[†] Archiv der Heilk, 1867, p. 472.

[‡] Ibid. 1867, p. 84.

[§] M'William, Epidem. Society Trans. vol. i. p. 274.

[||] Report of the Sanitary Commissioners with the Government of India for 1867. Calcutta, 1868.

[¶] Dr. J. M. Cuningham has, however, since renounced the theory of the water carriage of cholera.

[**] *Vide* Report on the Sanitary Administration of the Punjaub for 1867, and subsequent years, by A. C. C. De Renzy, Esq. (Cases of Peshawur and Amritzur.)

[††] See also the remarkable case of the Yerranda gaol, reported by Surgeon-Major H. Blanc. Out of 1279 prisoners there were 24 cases of cholera in 5 days, with 8 deaths. Of those 22 cases occurred among 184 prisoners employed as a road-gang, and only 2 among all the others variously employed. It was shown that the road-gang alone drank of water from the Mootla River, a little below the spot where the clothes of two cholera patients from the village had been washed and their bodies burnt a few days before. The rest of the prisoners drank the usual water supply laid on from a lake near Poonah. In the two cases among those otherwise employed direct infection was undoubted in one, as he attended on cholera patients, and, contrary to orders, took his meals in the cholera ward, and drank water that had been standing there; the other man slept near one of the first cases, the patient vomiting in his immediate vicinity.

[‡‡] I derive this information from a MS. essay of Dr Cattell.

2. The evidence derived from such local outbreaks is supported by that drawn from the history of more general attacks, in which districts supplied with impure water by a water company have suffered greatly, while other districts in the same locality, and presenting otherwise the same conditions, were supplied with pure water, and suffered very little. Thus the Registrar-General has shown that the districts supplied in 1853, part by the Lambeth Company with a pure water, and part by the Southwark Company with an impure water, suffered much less than the districts supplied by the latter company alone (the proportion was 61 and 94 cases respectively to 100,000 of population). Schiefferdecker, in Königsberg, has also given evidence to show the different extent in which districts in the same city supplied with pure and impure water suffer.[*]

In Berlin, in 1866, in the houses supplied with good water the number of houses in which cholera occurred was 36·6 per cent.; in the houses with bad water was 52·3 per cent.[†]

3. Additional arguments can be drawn from instances in which towns which could not have had water contaminated with sewage have escaped, and instances in which towns which have suffered severely in one epidemic have escaped a later one, the only difference being that, in the interval, the supply of water was improved. Exeter, Hull, Newcastle-on-Tyne, Glasgow, and Moscow are instances of this. Two very good cases are related by Dr Acland.[‡] The parish of St Clement was supplied in 1832 with filthy water from a sewer-receiving stream. In 1849 and 1854 the water was from a purer source. In the first year, the cholera mortality was great; in the last years, insignificant. Two jails were near each other; the one suffered, the other did not; the water was impure in one case from drainage, pure in the other. The jail with bad water having got a fresh supply, the cholera did not appear in the next epidemic. In Copenhagen a fresh water supply was introduced in 1859. Although cholera had prevailed very severely there previously, in 1865 and 1866 there were only very few cases. The future must show if this exemption was owing to the purer water.[§] In Haarlem, in Holland, cholera prevailed in great intensity in 1849. In 1866 it returned, and again prevailed as severely in all parts of the town except one. The part entirely exempted in the second epidemic was inhabited by bleachers, who, between 1849 and 1866, had obtained a fresh source of pure water.[||]

In looking back, with this new reading of facts, it would seem that some older reported cases of sudden cessation of cholera can be explained, such as the case of Breslau, in 1832, when the shutting up of a pump was followed by the very rapid decline of the disease. Doubtless, however, in other cases the causes of the cessation are different; heavy rain, by cleansing air and sewers, and by stopping the evolution of effluvia, will sometimes as suddenly arrest cholera. Most important evidence is given by Professor Förster of Breslau (Die Verbreitung der Cholera durch die Brunnen, Breslau, 1873). He shows that five towns of Silesia (of 5000 to 12,000 inhabitants) are entirely free from cholera, which never spreads, even when introduced. The only common condition is a water supply from a distance which *cannot* be contaminated. In Glogau (13,000) half the water is from a distance and half from wells: those using the former remain free, those using the latter are attacked. In one case in Breslau, on a well becoming contaminated, eleven persons were immediately attacked. Dantzig and Königsberg used formerly *to suffer equally: Dantzig, having a new water-supply,* does not suffer; *Königsberg, with its original supply, continues to do so.*[*]

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[*] See Report on Hygiene, Army Med. Dept. Report, vol. xii. p. 241.

[†] Die Kanalisation von Berlin, 1868. p. 30.

[‡] Cholera in Oxford in 1854, by H. W. Acland, M.D., p. 51.

[§] Hornemann in Virchow's Archiv, band 53, p. 156.

[||] Ballot, British Med. Journal, April 1869.

*So also other curious facts in the history of cholera become explicable.* The prevalence of cholera in Russia, with an out-door temperature below zero of Fahr., has always seemed an extraordinary circumstance, and it appeared only possible to explain by supposing that, in the houses, the foul air and the artificial temperature must have given the poison its necessary conditions of development. But Dr Routh has pointed out[†] that, in the poorer Russian houses, everthing is thrown out round the dwellings; then owing to the cold, and the expense of bringing drinking water from a distance, the inhabitants content themselves with taking the snow near their houses and melting it. It is thus easy to conceive that, if cholera evacuations are thus thrown out, they may be again taken into the body. This is all the more likely, as cholera stools have little smell or taste, and, when mixed even in large quantity with water, are indetectable by the senses.

We may therefore conclude that the cholera evacuations, either at once or after undergoing some special fermentative or transformation change, pass into drinking water or float about in the atmosphere. In either case they are received into the mouth and swallowed, and produce their effects directly on the mucous membrane, or are absorbed into the blood. The relative frequency of each occurrence, the incubative period, and the severity of the disease produced, are points still uncertain.

C. Macnamara states ("Asiatic Cholera," p. 330) that the dangerous period is when the water into which cholera stools are passed is swarming with vibriones, and that when ciliated infusoria appear danger is over. He speaks strongly on this point, and from actual experience.

In addition to the production of cholera from drinking water containing the cholera stools, it has been supposed that the use of impure water of any kind *predisposes* to cholera, though it cannot absolutely produce the disease. The facts already quoted on the influence of the Lambeth water seem to support this view; but some German evidence in 1866 does not favour it.[‡] If the water acts in this way, it can only be by causing a constant tendency to diarrhœa, or by carrying into the alimentary canal organic matter which may be thrown into special chemical changes by a small quantity of cholera poison, which has been introduced with air or food and swallowed.

### *Yellow Fever.*

As, like dysentery, typhoid fever, and cholera, the alimentary mucous membrane is primarily affected in yellow fever, there is an *a priori* probability that the cause is swallowed also in this case, and that it may possibly enter with the drinking water. But no good evidence has been yet brought forward.

Boudin[§] quotes a case from Rochard in which a French frigate (in 1778) took in water at San Jago, where yellow fever prevailed. Some days afterwards yellow fever broke out with such violence, that two-thirds of the crew were attacked. "And the proof that the only cause was the water," says Rochard, "was that the persons living with the captain had with them jars filled with water from Europe, and all escaped." Boudin very properly observes, *that this evidence is very defective; but yet we must remember how completely the propagation of marsh and typhoid fevers, and of cholera by water, has been overlooked, and how exactly this* sudden and extensive attack resembles the case of the Argo.

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[*] In India also similar results are found. Cullen cites the case of Hurda, rendered free from cholera by improved conditions of water supply. Payne reports that the new water supply of Calcutta has had the strongest effect in diminishing the mortality from cholera. See also the Report on the Cholera in America in 1873, for cases of water carriage.

[†] Fæcal Fermentation, p. 24.

[‡] See Report on Hygiene, Army Medical Dept. Report, vol. vii. p. 352.

[§] Traité de Géog. et de Stat. Méd. 1858, t. i. p. 141.

The Barrack Commissioners have also directed attention to the fact of the great impurity of the water at Gibraltar at the time of the yellow fever epidemic.

### *The other Zymotic Diseases.*

No decided evidence has yet been given that any other of the specific diseases are propagated in this way, but Dr Macadam has brought some evidence to show that erysipelas and throat ulcer may have a water origin,[*] and Dr Menzies has stated that, in Naples, cases of (*Edinburgh Med. and Sur. Journal*, Sept. 1872) diphtheria occurred, which he thinks were caused by contaminated water. The evidence is not, however, at present sufficient to prove this.

### 4. DISEASES OF THE SKIN, AND SUBCUTANEOUS TISSUES.

A curious endemic of boils occurred in the vicinity of Frankfort in 1848. It was confined to a small number of persons, and presented favourable opportunities for investigation. An elaborate inquiry was made by Dr Clemens,[†] which certainly seems to indicate that the complaint was caused by drinking water containing sulphuretted hydrogen gas, which was set free in some large chemical works, and was washed down by the rains into the brooks from which drinking water was derived. The case is most elaborately and logically argued, but it certainly seems remarkable that other instances of the same kind should not have been observed, especially as in some trades there is disengagement of large quantities of $SH_2$ into the atmosphere, and as the drinking of sulphuretted springs is so common.

The peculiar forms of boil or ulcer common in many cities in the East have been in some cases referred to the water. The Aleppo evil, the Damascus ulcer, and some other diseases of an analogous kind, which have the peculiarity of occurring only once in life, are possibly more connected with the true contagions; but the unhealthy boils or ulcers so common in India, especially in the north-west and along the frontier, are probably connected with bad water. The so-called Delhi boil has much decreased in frequency since the waters of the Jumna were used instead of the impure well water,[‡] but, on the other hand, Fleming's observations have thrown doubt on the fact of the water being to blame.[§] With regard to the frontier ulcers in India, Dr Alcock (35th Regt.) has given some curious evidence, which seems to connect them with vegetable detritus and the evolution of sulphuretted hydrogen.

The elephantiasis of the Arabs (the so-called Barbadoes leg or Pachydermia) has been ascribed to organic impurities in water, but on no very stringent evidence.

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[*] Trans. of the Royal Scottish Society of Arts, 1867.

[†] Henle's Zeitschrift für Nat. Med. 1849, vol. viii. p. 215.

[‡] See Annual Report of San. Com. with the Government of India for 1867, p. 178 (1868). Some excellent analyses of the Delhi waters are given by Dr Sheppard; *vide* Dr Macnamara's Second and Third Reports of the analyses of potable waters in the Bengal Presidency. Calcutta, 1868.

[§] The later observations of Drs D. Cunningham and T. Lewis have tended, on the other hand, to weaken the [illegible] of Fleming, and to show that the water is probably to blame.

### 5. DISEASES OF THE BONES.

Water, impregnated with sulphurous acid, gives rise in cattle to a number of serious symptoms, among others to diseases of the bones. The sulphurous acid evolved from the copper works at Swansea has caused numerous actions on account of the loss of herbage and cattle. Rossignol[*] states that water *highly charged with calcium carbonate and sulphate was found to give rise to exostoses in horses; pure water being given, the bones ceased to be diseased. Hard water is said to make horses' coats rough.*

### 6. CALCULI.

It has long been a popular opinion that drinking lime waters gives rise to calculi (calcium phosphate and oxalate). Several medical writers have held the same opinion, and have adduced individual instances of calculi (phosphatic?) being apparently caused by hard waters, and cured by the use of soft or distilled water. On a large scale, statistical evidence is, as far as I know, wanting. The excess of cases of calculi in Norwich and Norfolk generally is not, in Dr Richardson's opinion, attributable to the water.[†] Dr J. Murray, of Newcastle, has lately given some evidence[‡] to show a connection between the lime waters and calculi, especially phosphatic, but it does not appear to be more convincing than that previously adduced.

At Canton stone is common, while at Amoy, Shanghai, Ningpo, and other places, it is not met with. The cause of the difference is not known, but it is not chalk water, as the Chinese always drink boiled water.[§]

Professor Gamgee, however, states that sheep are particularly affected by calculus in the limestone districts.

### 7. GOITRE.

The opinion that impure drinking water is the cause of goitre is as old as Hippocrates and Aristotle, and has been held by the majority of physicians. The opinion may be said actually to have been put to the test of experiment, since both in France and Italy the drinking of certain waters has been resorted to, and apparently with success, for the purpose of producing goitre, and thereby gaining exemption from military conscription.[||] And this is supported by the evidence of Bally, Coindet, and by many of the French army surgeons, who have seen goitre produced even in a few days (8 or 10) by the use of certain waters.[¶] While, conversely, Johnston saw goitre, which was common in a jail, disappear when a pure water was used.[**] Apart from this, the evidence for the causation by water is extremely strong, many cases being recorded where, in the same village, and under the same conditions of locality and social life, those who drank a particular water suffered, while those who did not do so escaped.[*] The latest author who has written on this subject, and who has accumulated an immense amount of evidence, M. Saint-Lager, expresses himself very confidently on the point.

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[*] Traité d'Hygiène Militaire, 1857, p. 357.

[†] Med. History of England; Medical Times and Gazette, 1864, p. 100.

[‡] British Medical Journal, September 1872.

[§] Dr Wang in Chinese Customs Report for 1870, p. 71.

[||] Among other evidence on this point, the late work of M. Saint-Lager (Sur les causes du Cretinisme et du Goitre endémique, Paris, 1867) may be cited (p. 191, *et seq.*), as he appears to have carefully looked into the evidence. See also Baillarger (Comptes Rendus de l'Acad. t. lv. p. 475), who also states, though this has been denied by Rey, that horses and mules become affected from drinking the water of the Isère.

[¶] Encyclopædia of Practical Medicine, vol. i. art. Bronchocele, p. 326.

[**] Edin. Monthly Journal, May 1855.

The impurity in the water which causes goitre is not yet precisely known. It is certainly not owing to the want of iodine, as stated by Chatin, and there is little probability of its being caused by organic matters, by fluorine, or by silica. On the other hand, the coincidence of goitre with sedimentous water is very frequent. Since the elaborate geological inquiries of M. Grange[†] and the analyses of the waters of the Isère, magnesian salts in some form have been often considered to be the cause, to which many add lime salts also; and certainly the evidence that the waters of goitrous places is derived from limestone and dolomitic rocks, or from serpentine in the granitic and metamorphic regions, is very strong. The investigations now include the Alps, Pyrenees, Dauphiné, some parts of Russia, Brazil, and districts in Oude in North-West India. A table compiled from Dr M'Clellan's work[‡] is very striking:—

*Goitre and Cretinism in Kumaon (Oude).*

| Water derived from | Percentage of Population affected. | |
|---|---|---|
| | With Goitre. | With Cretinism. |
| Granite and gneiss, . . . . . | 0·2 | 0 |
| Mica, slate, and hornblende, . . | 0 | 0 |
| Clay slate, . . . . . . . . . . | 0·54 | 0 |
| Green sandstone, . . . . . . | 0 | 0 |
| Limestone rocks . . . . . . . | 33 | 3·0 |

There are, however, not wanting analyses of water of goitrous regions which show that magnesia may be absent (in Rheims, according to Maumené; in Auvergne, according to Bertrand; in Lombardy, according to Demortain; while Saint-Lager enumerates other cases), while it has been also denied that there need be any excess of lime. M. Saint-Lager, basing his opinion partly on these negative instances, partly from his own experiments with the soap-test, which show no relation between hardness of water and goitre, and partly from the negative results of experiments on animals with calcium sulphate and magnesian salts, denies altogether the connection between goitre and calcium and magnesium sulphates and carbonates. He states also that M. Grange has now himself given up the belief of magnesia being the essential agent of goitre,[§] and argues that the constituent of the water which is the actual cause is either iron pyrites (ferrum sulphide), or more infrequently copper or some other metallic sulphide. And he explains M'Clellan's results by the supposition, based on an expression of that writer, that in the limestone districts of Kumaon the water had traversed the metalliferous strata of the rocks. Saint-Lager does not, as far as I see, support his opinion by actual chemical analyses, but he brings forward geological evidence on a large scale, to prove that the endemic appearance of goitre coincides with the metalliferous districts. He has also made experiments on animals with iron salts, which do not appear conclusive, though he believes he produced in some cases an effect on the thyroid. His hypothesis seems to me to fail from this want of chemical analysis. He has made out a case for inquiry rather than for conclusion. It seems clear that while it may be admitted that impure water is the cause of goitre, there ought to be renewed chemical analyses, and it would not seem difficult to decide such a point by a properly conducted inquiry.

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[*] Saint-Lager (*op. cit.*) cites several strong cases (p. 192 *et seq.*).

[†] Ann. de Chimie et de Phys., vol. xxiv. p. 364.

[‡] Medical Topography of Bengal. I have included the facts on cretinism also, without desiring to express any opinion on the relation between goitre and cretinism.

[§] Sur les causes du Cretin. et du Goitre, p. 237.

In some observations lately made by Dr Ferguson on the goitrous part of the Baree Doab district[*] (a boulder-gravel subsoil), the water is stated to be largely charged with lime. In the jail at Durham, Johnston[†] states that when the water contained 77 grains per gallon (chiefly of lime and magnesian salts), all the prisoners had swellings of the neck; these disappeared when a purer water, containing 18 grains in the gallon, was obtained.[‡]

Goitre may be rapidly produced. Bally noticed that certain waters in Switzerland would cause it even in eight or ten days, and cases almost as rapid have occurred in other places.[§]

### 8. ENTOZOA, OR OTHER ANIMALS.

Whereas the *Tænia solium* and the *Tænia mediocanellata*, and many entozoa, find their way into the body with the food,[||] the two forms of the *Bothriocephalus latus* (*T. lata*) may pass in with the drinking water.[¶] Both embryo and eggs (but principally, or perhaps entirely, the former) exist in the river water. The ciliated embryo moves for several days very actively in water; it may then, after a time lose its ciliary covering, and then, not being able to move further, perishes; or it may find its way into the body of some animal, and there develop into the *Bothriocephalus latus.*

It is most common in the interior of Russia, Sweden, in part of Poland, and in Switzerland.

*Distoma hepaticum* (*Fasciola hepatica*).—The eggs are developed in water, and the embryos swim about and live, so that introduction in this way for sheep is probable, and for men is possible.

The *Ascaris lumbricoides* (Round-worm) appears also sometimes to enter the body by the drinking water. At Moulmein, in Burmah, during the wet season, and especially at the commencement, both natives and Europeans, both sexes and all ages, were, during my service thirty years ago, so affected by lumbrici that it was almost an epidemic.[**] The only circumstance common to all classes was that the drinking water, drawn chiefly from shallow wells, was greatly contaminated by the substances washed in by the floods of the excessive monsoon which prevails there. Dr Paterson has also noticed similar facts in England (Aitken's "Practice of Medicine," 6th edition, i. p. 124).

Leuckart[††] has no doubt of the passage of the ascarides' eggs into drinking water; and, indeed, they have been actually seen in drinking water by Mosler.[*] But it seems yet doubtful (as all experiments have failed in producing from the drinking water the worms in animals) whether the eggs alone will suffice, and it seems possible that they must pass through some other host before developing in the human intestine. This is also the opinion of Cobbold. Mosler attributed in his case much influence to the large amount of vegetable food taken by the persons affected.

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[*] Sanitary Administration of the Punjab for 1871, Appendix 4, p. 33.

[†] Edin. Monthly Journal, May 1855.

[‡] In Nottingham the people attribute Goitre to hardness of water. Generally it appears only with magnesium limestone.

[§] Many instances are recorded in the French Military Medical Journal, Recueil de Mém. de Méd. Mil., of the acute goitre produced in a few days.

[||] Dr Oliver's observations in India show that cattle may get tænia ova from the water; so that men may do the same. (See Aitken's Med., 6th ed. vol. i. p. 179.)

[¶] See especially a paper by Dr Knock in the Peterburger Med. Zeitsch. for 1861. An abstract is given in the Lancet, Jan. 25, 1862; and the paper in full is printed in Virchow's Archiv, band xxiv. 453. Cobbold, however, doubts the direct entrance in this way, and thinks it more probable that fish form the *host* for the ova, which after development in the first, may find their way into the bodies of men who eat the fish.

[**] The native treatment is the powder of a fungus (Wah-mo), derived from the female bamboo. It is most useful. See paper by the author in the London Journal of Medicine, 1849.

[††] Die Menschlichen Parasiten, band ii. p. 220.

The *Dochmius duodenalis* (*Strongylus duodenalis*, *Anchylostomum seu Sclerostoma duodenale*) would appear from Leuckart's statement[†] to be introduced by impure water.[‡]

*Filaria Dracunculus* (Guinea-worm).—The introduction by water of the Filaria has long been a favourite opinion. It has been a matter of debate whether it is taken into the stomach as drink, and thence finds its way (like the Trichina, to the muscles) into the subcutaneous cellular tissue, or whether it penetrates the skin during bathing or wading in streams. The latter opinion seems to be the most probable in the majority of cases.[§]

Boiling the water before drinking appears to have some preservative effect.[||] It is possible that the *Filaria sanguinis hominis* of Lewis may also be introduced by drinking water.

*Bilharzia hæmatobia.*—From the observations of Griesinger, John Harley,[¶] and Cobbold, there seems no doubt that the embryos of this entozoon live in water, and the animal may be thus introduced probably by the medium of some other animal. Dr Batho doubts, however, this introduction by water, since the entozoon occurred in persons using rain water and pure mountain stream water. ("Army Med. Rep." vol. xii. p. 504.)

*Leeches.*—Reference has already been made to the swallowing of small leeches, which fix on the pharynx, and in the posterior nares. Cleghorn ("Diseases of Minorca," 1768, p. 38) noticed that coughs, nausea, and spitting of blood were thus caused. In a march of the French near Oran, in Algiers, more than 400 men were at one time in hospital from this cause. In some cases the repeated bleedings from the larynx have simulated hæmoptysis and phthisis, and have produced anæmia. A leech, once fixed, seldom falls off spontaneously. In India no accidents of this kind are on record, yet we must assume that they occasionally occur.

### 9. LEAD, MERCURY, ARSENIC, COPPER, AND ZINC POISONING.

It is only necessary to mention the fact of metals passing into the drinking water, either by trade refuse being poured into streams, or by the water dissolving the metal as it flows through pipes or over metallic surfaces. (See page 15.)

In 1864 a factory at Basle discharged water containing arsenic into a pond, from which the ground and adjacent wells were contaminated, and severe illness in the persons who drank the well water was produced. (Roth and Lex, "Milit. Gesundsheitpfl." p. 41.)

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[*] Virchow's Archiv, band xviii. p. 249.

[†] Ibid. band ii. p. 455.

[‡] The importance of the discovery of Griesinger (Archiv für Phys. Heilk, 1854, p. 555), that the so-called widely spread Egyptian chlorosis, is caused by the *Dochmius duodenalis*, has hardly been sufficiently appreciated. Not only anæmia and liver diseases, but symptoms referred to dysentery and hæmorrhoids, are often also produced. And as similar facts have now been observed in Brazil, Arabia, and Madagascar, it seems impossible but that in India the formidable affections caused by the Dochmius should not be common.

[§] See Dr Aitken's long and excellent chapter on this disease, in the first volume of his Practice of Medicine, 6th edition, p. 139, *et. seq.*, for a discussion on the water and earth question.

[||] Greenhow in Indian Annals, 1856, p. 557.

[¶] Med. Chir. Trans., vol. xlvii. p. 65, and vol. lii. p. 379.

### *General Conclusions.*

1. An endemic of diarrhœa, *in a community*, is almost always owing either to impure air, impure water, or bad food. If it affects a number of persons suddenly, it is probably owing to one of the two last causes, and if it extends over many families, almost certainly to water. But as the cause of impurity may be transient, it is not always easy to find experimental proof.

2. Diarrhœa or dysentery, constantly affecting a community, or returning periodically at certain times of the year, is far more likely to be produced by bad water than by any other cause.

3. A very sudden and localised outbreak, of either typhoid fever or cholera, is almost certainly owing to introduction of the poison by water.

4. The same fact holds good in cases of malarious fever, and, especially if the cases are very grave, a possible introduction by water should be carefully inquired into.

5. The introduction of the ova of certain entozoa by means of water is proved in some cases—is probable in others.

6. Although it is not at present possible to assign to every impurity in water its exact share in the production of disease, or to prove the precise influence on the public health of water which is not extremely impure, it appears certain that the health of a community always improves when an abundant and pure water is given; and, apart from this actual evidence, we are entitled to conclude, from other considerations, that abundant and good water is a primary sanitary necessity.

## SECTION V.

## EXAMINATION OF WATER FOR HYGIENIC PURPOSES.*

The analysis of water for hygienic purposes has for its object to ascertain whether the water contains any substances either suspended or dissolved which are likely to be hurtful. There are some substances which we know are not likely to do any harm, such as carbonate of sodium, calcium, and magnesium in small quantities. Others are at once viewed with suspicion as indicating an animal origin, and therefore being probably derived from habitations or decaying bodies. In other cases substances in themselves harmless, such as nitrates, nitrites, and ammonia, are suspicious from implying the co-existence of, or the previous contamination of the water by nitrogenous substances. The difficulties in the hygienic examination of water are not inconsiderable. A judgment must be generally come to from a collation of all the evidence, rather than from the results of one or two tests.†

### *Collection.*

Great care must be taken that a fair sample‡ of the water is collected in perfectly clean glass vessels (not in earthenware jars)—Winchester quarts are most convenient—which should be repeatedly washed out with some of the water to be examined. The bottle should be stoppered; a cork should be avoided, except in great emergency; but if used it should be quite new, well sealed, and tied down.*

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* Dr F. N. Macnamara has prepared for use in India "A Scheme for the Analysis of Potable Waters." It is an admirable scheme, and I have made use of some parts of it.

† Boxes containing tests and apparatus sufficient to carry out the analyses recommended in this book are sold by Messrs Savory and Moore, New Bond Street, London, and by Messrs Griffin & Sons, Garrick Street, Covent Garden.

‡ Thus, in taking water from a stream or lake, the bottle ought to be plunged below the surface before it is filled. In drawing from a pipe, a portion ought to be allowed to run away first, to get rid of any impurity in the pipe. In judging of a town supply, samples should be obtained direct from the mains, as well as from the houses.

### *Examination.*

For a complete investigation at least a gallon is necessary, but with a litre or a couple of pints a pretty good examination can be made. The examination ought to be undertaken as soon after collection as possible, say in 48 hours (Wanklyn). Pending examination it ought to be kept in a dark cool place.

It should be commenced by noting the coarser physical characters, such as the colour, transparency,† smell, and taste of the water.

The *smell* and *taste* of the water give some indications; for the smell the water may be warmed, or distilled, when the odour of fæcal matter is often brought out clearly both in the distillate and residue. If the water is put in a stoppered bottle, which it half fills, and is exposed to light, and then opened and smelt after a few days, commencing putrefaction, or the formation of butyric acid, or something similar, can sometimes be detected. Tiemann recommends that the water should be heated to 110° or 120° Fahr.; if hydrogen sulphide be present add a little copper sulphate, which precipitates it and permits any putrid smell to be perceived.

Taste is an uncertain indication. Any badly tasting water should be rejected, or purified before use. Suspended animal organic matters often give a peculiar taste, so also vegetable matters in stagnant waters. Some growing plants, as lemnia, and pistia, give a bitter taste; but most growing plants have no taste. Perfectly dissolved animal matter is frequently quite tasteless. As regards dissolved mineral matters, taste is of little use, and differs much in different persons. On an average—‡

| | | | | | |
|---|---|---|---|---|---|
| Sodium chloride | is tasted | when it reaches | 75 | grains per | gallon. |
| Potassium „ | „ | „ | 20 | „ | „ |
| Magnesium „ | „ | „ | 50 to 55 | „ | „ |
| Calcium sulphate, | „ | „ | 25 to 30 | „ | „ |
| „ carbonate, | „ | „ | 10 to 12 | „ | „ |
| „ nitrate, | „ | „ | 15 to 20 | „ | „ |
| Sodium carbonate, | „ | „ | 60 to 65 | „ | „ |
| Iron, . , | „ | „ | ·2 | „ | „ |

Iron is thus the only substance which can be tasted in very small quantities. A permanently hard water has sometimes a peculiar *fade*, or slightly saline taste, if the total salts amount to 35 or 40 grains per gallon, and the calcium sulphate amounts to 6 or 8 grains. The taste of good drinking-water is due entirely to the gases dissolved; water nearly free from carbonic acid hardness, such as distilled water, is not so pleasant as the brisk well carbonated waters; it may be called flat, but it is difficult to define the kind of taste or absence of it.§

The conditions of colour and transparency are given below.

The coarser physical examination gives few indications of value, and if a water is reputed good on the evidence of this examination alone, it should be so stated.

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* W. O. Circular 82, June 1876, directs water to be sent in stoppered glass-bottles.

† Gérardin also recommends the *lustre* to be noted.

‡ Dr De Chaumont, Army Medical Report for 1862 (vol. iv. p. 355.)

§ Arguing from the apparent preference many persons have for water containing some saline matter, Wanklyn has suggested the addition of sodium chloride to drinking water, to the extent of 50 grains per gallon.

The further and complete examination of the water may be conveniently divided into two parts: the examination of the suspended, and of the dissolved matters.

## SUB-SECTION I.

### EXAMINATION OF SUSPENDED MATTERS.

The suspended matters may be either mineral (sand, clay, chalk, fine films of mica, iron peroxide), or dead animal or vegetable matters, or living creatures (plants and animals).

*To examine the colour and detect the presence of Suspended Matters.*

Pour some of the water into a tall white glass vessel placed on white paper or plate, and look down it; a depth of 2 feet is desirable, but a stratum of a foot or 18 inches will give valuable information. A similar glass with distilled water should be used for comparison. Substances giving colour and opacity to water can be thus detected when merely looking through the water gives no indication. Perfectly pure water has a bluish tint, and several feet of thickness do not obscure the bottom of the vessel. As water becomes turbid the bottom of the vessel is less distinctly seen, or is obscured altogether, by perhaps only a few inches of water. The depth obscuring the bottom of the vessel should be noted, and the kind of colour; a green colour indicates vegetable impurity generally, a yellow or brown colour animal impurity, except in peat-water.

Living animals moving through the water, like the water-flea or cyclops, are best detected by looking through the water. Any water which is very turbid is a suspicious one.*

*To determine the nature of the Suspended Matters.*

Suspended sand or clay gives a yellow, or yellow-white turbidity; vegetable humus and peat give a darkish, sewage gives a light brown colour; but the colour or turbidity alone is a very insufficient test. Then boil the water, and pour it back into the long glass. Sand, chalk, and heavy particles of the kind will be deposited; finely suspended sewage and vegetable matter is little affected, unless it be a chalk water, when the deposit of calcium carbonate may carry down the suspended matter. When the water is commencing to boil, smell it to see if there is any trace of sewage.

### MICROSCOPIC EXAMINATION.†

The examination with the microscope can, however, alone give accurate information of the nature of the suspended matters. Very high powers (1000 or 1200 diameters) are necessary for a complete examination, though lower powers will give much information.

If the matter is entirely suspended, a drop of the water must be taken at once; but when it can be obtained, a little of the sediment is more satisfactory. To get a sediment, the water should be placed in a conical glass, carefully covered and allowed to stand for a few hours; and the upper part of the water is then poured away or syphoned off. In special cases, where it is important to know the exact condition of the suspended matters, before they undergo change by the action of the atmosphere of the room or laboratory where they may be kept, they may be collected in vacuum tubes, which may be sealed. A very small amount of sediment can be thus got at. An immense number of dead and living things may be found in water, which it would be impossible to enumerate, but which may be conveniently divided into two great and several minor headings.

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* Gérardin recommends that the lustre (*éclat*) should be noted, and considers it an index of the presence of oxygen in solution; a pure, well aerated water has a brilliant, sparkling, or adamantine lustre, whilst an impure, badly aerated water has a dull or vitreous lustre.

† For a good resumé of this part of the examination, reference may be made to Professor Macdonald's excellent work, "A Guide to the Microscopic examination of Drinking-water, by J. D. Macdonald, R.N., F.R.S., Deputy Inspector-general of Hospitals and Fleets, Professor of Naval Hygiene, Army Medical School."

### 1. *Inanimate Substances.*

(*a*) Mineral particles are tolerably easily known; sand has large angular particles; clay and marl round smooth globules unaffected by acids; chalk round often glistening bodies dissolved by acid.

(*b*) Vegetable matters: portions of wood, leaves, bits of the veins; parenchyma or ducts are easily recognised. When vegetable tissue is more decomposed nothing is seen but a dark, opaque, structureless mass. Any dark formless mass of this kind in water is almost certainly decayed vegetable matter. Bits of textile fabrics (cotton, linen) are not uncommon, and are important as indicating that the water is contaminated with house refuse. So also the cells of the potato, or spiral threads of cabbage and other vegetables used by men, are important as indications of the same kind.

(*c*) Animal matters, consisting of bits of wool, hair, remains of animals of all kinds, such as wings and legs of insects, spiders and their webs, portions of the skin of water animals or of fish, &c., are not uncommon. Sewage matters having a darkish brown or reddish colour, and often in globular masses, and thus distinguishable from the flatter and more spread-out vegetable matter, are sometimes seen. In the London water, as supplied twenty-five years ago, Hassall recognised these little "ochreous" masses, and found that nitric acid brought out a pink tint. He thought them to be portions of muscular fibre, tinged with bile. Epithelium (from the skin of men)* and hairs of animals are not unfrequent. The identification of these matters is of moment, as indicating the particular source of the contamination. Anything which can be unequivocally traced to the habitations of men must always cause the water to be regarded with suspicion, as if one substance from a house can find its way in, others may do so.

### 2. *Living Creatures.*†

These are often found in the sediment, but sometimes also float in the water above the sediment. They are almost innumerable, and as immature forms and various stages of development are seen, it is often difficult or impossible to name all of them.

(*d*) Bacteria, vibriones, or microzymes. Under these terms are meant the small points or jointed rods, sometimes moving rapidly sometimes slowly or motionless. Distinctions are made between these three by some, while by others the three terms are used as synonyms.‡ High powers (and preferably with immersion lenses) are required to see them properly. When they appear in water it is necessary, as Lex[*] has shown, that besides oxygen three conditions must be present—(1) an organic carbonaceous substance; (2) a nitrogenous substance, which need not be organic—a nitrate, for example, will well nourish bacteria, and is reduced to nitrite by their growth; (3) a phosphate, which, however, may be in exceedingly small quantity. The bacteria may either originally exist in the water, or be introduced. Burdon-Sanderson's experiments, however, are not favourable to the introduction of bacteria from the air, though, as noticed under *Air*, large numbers of cells which seem to belong to the same class can be obtained from the air. It appears from Burdon-Sanderson's observations, that the germs (if the term be allowed) of bacteria may exist in water and be indetectable by the highest microscopic powers, or even by Tyndall's test of the electric beam. To detect these the test by cultivation, or what may be called the *microzyme test for water*, can be employed. Take a little recently prepared clear Pasteur's fluid,[‡] boil it, and put one or two C.C. into a test tube previously strongly heated to 356° Fahr., drop in three or four drops of the water, and close the mouth of the tube with cotton wool. If microzymes or their germs exist in the water, in a few days the liquid becomes milky from countless bacteridia.

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* Epithelium from the skin breaks down slowly in water; I detected some in unfiltered Thames water in January 1869, and on the 31st May some of the same water preserved in a bottle showed quite distinctly the scales and nuclei. The collection of the water, the sending in a barrel from Teddington to Netley, and the soakage in the water for five months, had not destroyed the epithelium. Epithelium from the mouths of cattle is sometimes found. This was the case in some water examined at Netley, got from a catch-pit in Parkhurst Forest.

† Numerous plates of the various organisms found in the Thames water have been given by Hassall. (Microscopic Examination of the Water supplied to London, by A. H. Hassall, M.D., 1850. Food and its Adulteration, by same author, 1876.)

‡ Frequently spoken of as Bacteroids and smaller forms as Bacteriform puncta.

As, however, even distilled water and the purest ice-water contain bacteridia, the test cannot be used as an indication of good or bad water, except in connection with others, and with due regard to temperature, which has a great effect. All it will show is, that the greater or less rapidity of appearances of opalescence will prove that microzymes are more or less abundant.

The present view is, that while it has not been conclusively shown that bacteria or vibriones are in themselves hurtful (though they are so held by some observers), their presence indicates the coexistence of certain organic substances and putrefaction, and putrefactive substances in water are certainly dangerous.

The spirillum can also be often detected in water. In addition to microzymes the water will always contain various allied protozoa, which are usually termed monads or zooglœa, and which seem to have the same significance as bacteridia.[§]

(*e*) Rhizopoda, especially amœbæ and similar forms, may often be detected with high powers. They appear to indicate, like bacteridia, the existence of putrefying substances, but this is not yet certain.

(*f*) Euglenæ (of different species, such as *E. viridis*, *E. pyrum*, &c.) are found in many waters, especially of ponds and tanks.[||] Ciliated, free, and rapidly moving infusoria, belonging to several kinds of common protozoa, such as kolpoda, paramecium, coleps, stentor, kerona, stylonichia, oxytricha, &c., are also found. The abundance of these bodies indicate, of course, that the water contains food for them, and this must be either vegetable or animal organic matter, but the mere presence of these infusoria will not show which it is. Hassall noticed, however, in 1850, that the Thames water below Brentford, where it was mixed with sewage, swarmed with paramecia, while at Kew, where the water was freer from sewage matters, they had almost disappeared. Subsequent observations have not, however, proved the relation between paramecia and animal matter in the water to be sufficiently constant to allow the former to be used as a test of the latter. Fixed or slow moving infusoria, as the vorticellæ, are also often seen.

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[*] Centralbratt, für die Med. Wiss., No. 20, 1872, p. 305.

[†] Eventually the nitrite disappears, nitrogen being liberated.

[‡] Pasteur's fluid is composed of 10 grammes of crystallised sugar; ·5 grammes of ammonium tartrate; ·1 of well-burnt yeast ash, and 100 C.C. of distilled water. It should be quite clear. It is a capital breeding-ground for microzymes or fungi.

[§] According to Dr Macdonald, "All analogy would go to indicate that the Zooglæa form of *Bacterium termo* may be regarded as the primary or normal state of this organism, the surrounding gelatinous matter being simply the representation of that which forms the indefinite form of *Microhaloa*, or *Palmella* for example." (*op. cit.* p. 14).

[||] There appears reason to believe that all or most of the flagellate animalcules are vegetable, and the minuter are (such as monas) probably connected with the reproduction of higher forms, uch as fungi.

(*g*) *Fungi.*—In any water which contains nitrogenous matter (of animal nature, at any rate), sugar, and a little phosphate, fungi will soon appear, and the spores, no doubt, enter from the atmosphere. Spores, spore-cases, and delicate mycelium can be seen, and often bacteridia co-exist. If fungi are found in water they indicate impurity, and such water should not be used if it can be avoided, or should be purified.* Boiling does not kill the fungi, according to Heisch; charcoal filtration does so according to the same observer, though Frankland has thrown some doubt on this point. Animal charcoal adds some phosphate to the water, and in this way might aid the growth of fungi. According to Warrington and Bischof spongy iron (obtained by calcining with charcoal the residue from burnt copper pyrites) gives off no phosphate, and water filtered through it is quite freed from fungi.

Heisch† states that sewage matter in water gives rise, when sugar is added to the water, to a peculiar fungus, which he describes as formed of very small, perfectly spherical transparent cells arranged in grape-like bundles; they grow rapidly into mycelia, and are attended with the special character of producing the odour of butyric acid. The mycelium soon disappears.

Dr Frankland doubts whether fungi, which are readily produced by adding sugar to sewage water, are distinctive of sewage, as apparently similar cells are caused by other animal matters.

The identification of the spores of fungi, and even of the mycelium as seen in water, is so extremely difficult that it would be at present rash to affirm that any fungoid elements are distinctive of fæcal matter. The butyric acid smell also is given off by so many impure waters that it could hardly be used as a test for fæces.

(*h*) Algæ and diatoms are found in almost all running streams, and algæ are also seen in many well waters. They cannot be held to indicate any great impurity; and to condemn water on account of their presence would be really to condemn all waters, even rain, in which minute algoid vesicles (protococci) are often found.

The forms of the various confervæ in water are very numerous; some being coloured green, at other times they are quite colourless, round, isolated, or clustered vesicles. The immature forms may not be easy of identification. The diatoms are always easily recognised and identified. In many waters the living objects in the above five classes comprise all that are seen, but in other cases there are animals of a larger kind.

(*i*) Hydrozoa, especially the fresh water polyps, are common in most still waters, and do not indicate any thing hurtful.

(*k*) Worms, or their eggs and embryos, belonging to the class Scolecida, may occur in water, and are of great importance. The eggs and joints of the tapeworm, the embryos of the Bothriocephali, the eggs of the round and thread worms, and perhaps the worms themselves, the Guinea-worm, and other kinds of Filaria; the eggs of *Dochmius duodenalis*, and other distomata, and the embryos of the Bilharzia, have all been recognised in water though it has not yet been shown that in all cases they can be thus introduced into the human body. Possibly the *Filaria sanguinis hominis* may be taken in drinking water, but evidence is wanting. The worms themselves cannot be overlooked, but both the eggs and the free-moving embryos are difficult of identification. The greatest care should be used in examining water to detect the ova. In India the abundance of minute Filariæ has led to the general term of "tank-worm" being applied.

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* In the cases of malarious fever at Tilbury Fort (Army Med. Reports, vol. xvii.) fungoid structures were found in the water whose use was coincident with the fever, but were absent from the water, following on whose use the fever ceased.

† Chemical News, June 1870.

The presence of even common Anguillulæ in water shows generally an amount of impurity, and such a water must be regarded with great suspicion. Small leeches also are not uncommon in both still and running waters.

The wheel animalcules are common enough, and cannot be regarded as very important, though certainly when they exist there must be a good deal of food for them, and consequently impurity of water.

(*l*) Entomostraca (such as the water flea, *Daphnia pulex*, fig. 2; the *Cyclops quadricornis*, fig. 3; the *Sida*, *Moina*, *Polyphemus*, and others) are very common in the spring; they occur in so many good waters that they cannot be considered as indicating any dangerous impurity. It is said that they are only found near (within one or two feet) of the surface.

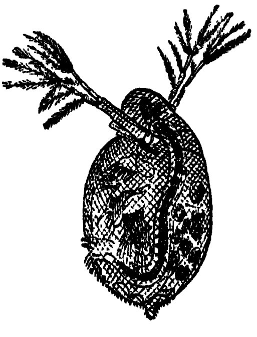


Fig. 2.

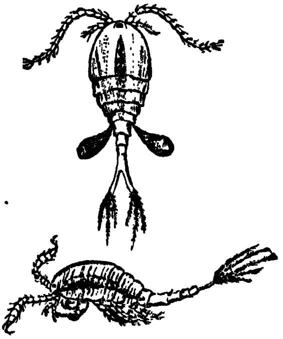


Fig. 3.

(*m*) There are, of course, many other tolerably large animals often found in water; the larvæ of the water-gnat (*Dytiscus*), the water-boatman, or skip-jack (*Notonecta glauca*), and the pupa form of many insects may be found, but they are chiefly in pond water.

So many are the objects in water that the observer will be often very much at a loss, first, to identify them, and secondly, to know what their presence implies. The best way is first to see what objects appear to be mineral, or non-living vegetable substances, and to fix the origin and estimate the quantity as far as it can be done. Then to turn to the living creatures and to look attentively for bacteridia, amœbæ, fungi, and ova, and small worms and leeches. If none of these exist, the water cannot be considered dangerous. Ciliated infusoria of various kinds, Diatoms, Desmids, and Algæ, are chiefly important in connection with microscopic evidence of decaying vegetable matters, and with chemical tests showing much dissolved organic impurity in the water.

The subjoined plates show the principal objects found in a deep well water (Plate I.); in a slow running stream (Plate II.); in Thames water taken in

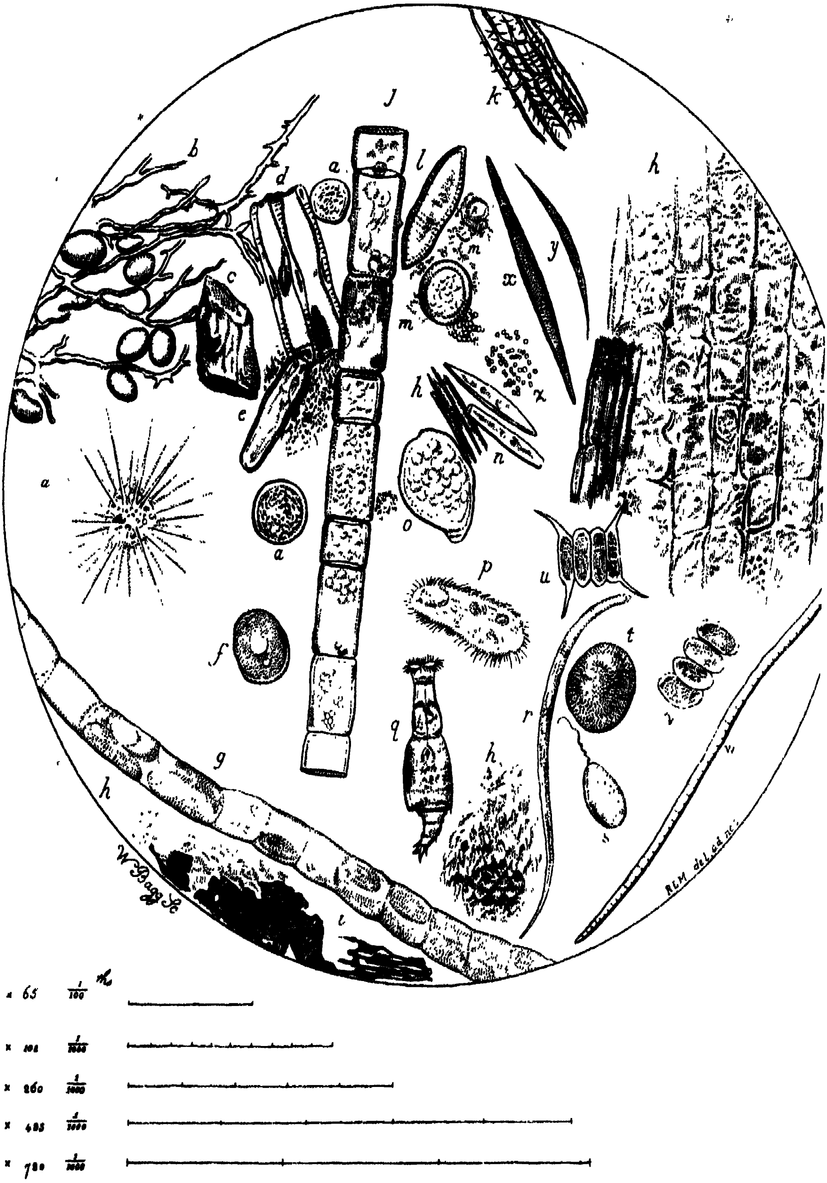
## DESCRIPTION OF PLATE I.

*Sediment from South wing Well, Netley, drawn with the* Camera lucida *at the distance of* 10 *inches from the centre of eye-piece to paper.*

The presence of infusoria and animals of low type indicates the presence of organic atter, animal or vegetable, and it is therefore important to note their presence ; but has not at present been shown that they are in themselves at all hurtful.

*aaa* Actinophrys Sol, early and complete stages, × 260.
*b* Supposed decomposing amœba-like expansions of Gromia fluviatilis, × 435.
*c* Fragment of carbonate of lime, × 435.
*d* Navicula viridis, × 435.
*e* Grammatophora marina ? × 435.
*f* Supposed encysted stage of Euglena viridis, × 435.
*g* Pinnate conferva, × 780.
*hhh* Fragments of decaying vegetable matter, × 65.
*ii* Fragments of carbonaceous substance.
*j* Part of conferva filament, Conferva floccosa ? showing the various conditions of the protoplasm in the old and new cells, × 435.
*k* Part of leaf of Sphagnum or bog-moss, × 108.
*l* Grammatophora marina, 435.
*m* Minute spores with zoospores ? × 435.
*n* Diatoma hyalinum, × 435.
*o* Cell with dividing protoplasm, × 435.
*p* Oxytricha lingua, × 260.
*q* Rotifer vulgaris, small, × 108.
*r* Anguillula fluviatilis, × 108.
*s* Peranema globosa, × 108.
*t* Statoblast of a fresh-water zoophyte ? × 108.
*u* Arthrodesmus incus, × 435.
*v* Minute Desmidiæ, Scenedesmus obtusus, × 780.
*w* Oscillaria (oscillatoria) lævis, × 780.
*x* Homœocladia filiformis ? × 435.
*y* Ankistrodesmus falcatus, × 435.
*z* Minute moving particles, × 435.—(?) Zoospores.

*(To Binder—To face Plate I.)*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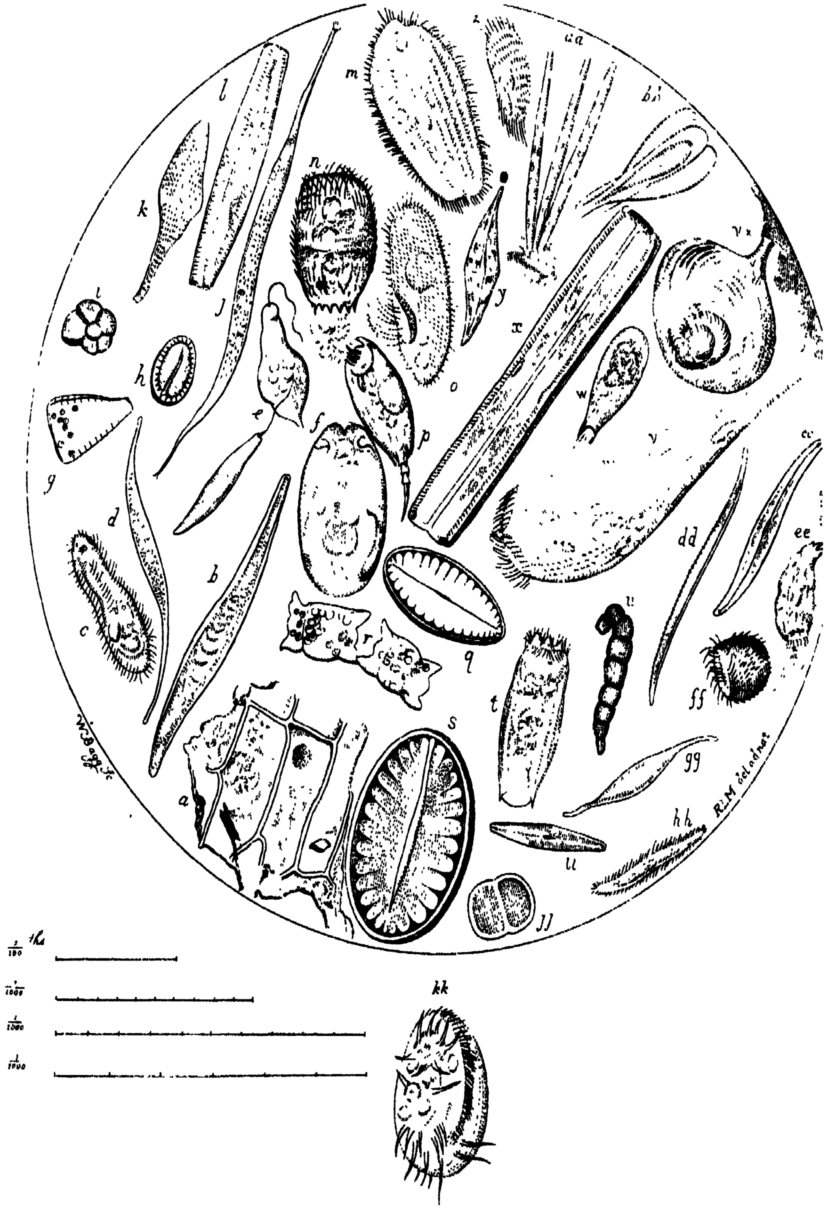
## DESCRIPTION OF PLATE II.

*nt of Ditch Water, drawn with the* Camera lucida *at the distance of* 10 *inches from eye-piece to paper.*

*a* Decaying vegetable matter, cellular tissue, × 108.
*b* Pleurosigma formosum, before dividing, × 170.
*c* Oxytricha gibba, × 108.
*d* Amphileptus anser, × 170.
*e* Euglena viridis, × 285.
*f* Supposed urceola of some rotifer, × 108.
*g* Surirella gemma, × 108.
*h* Do do. × 65.
*i* Foraminifera, × 65.
*j* Trachleocerca linguifera, × 65.
*k* Small Planaria ? ovisacs distended, × 65.
*l* Navicula viridis, × 285.
*m* Paramecium aurelia, × 170.
*n* Coleps hirsutus, × 285.
*o* Pleuronema crassa, 285.
*p* Monura dulcis, × 170.
*q* Surirella splendida, × 170.
*r* Biddulphia pulchella, × 285.
*s* Surirella striatula, × 170.
*t* Rotifer, Monolabis conica ? × 108.
*u* Aregma, spore cases, × 285.
*v* Stentor ceruleus ? do. *v.* × contracted, × 170.
*w* Trinema acinus ? × 170.
*x* Pinnularia grandis, × 170.
*y* Gyrosigma angulatum before dividing, × 170.
*z* Alyscum saltans ? × 170.
*aa* Synedra ulna, × 170.
*bb* Amphiprora alata, × 285.
*cc* Gyrosigma Spencerii, × 285.
*dd* Nitzschia sigma, × 170.
*ee* Brachionus angularis, × 170.
*ff* Young Vorticella ? × 170.
*gg* Gyrosigma fasciola, × 285.
*hh* Trachelius strictus, × 285.
*ii* Cocconema Boeckii, × 170.
*jj* Confervoid cell ? with divided protoplasm, × 285.
*kk* Euplotes Charon, × 170.

*(To Binder—To face Plate II.)*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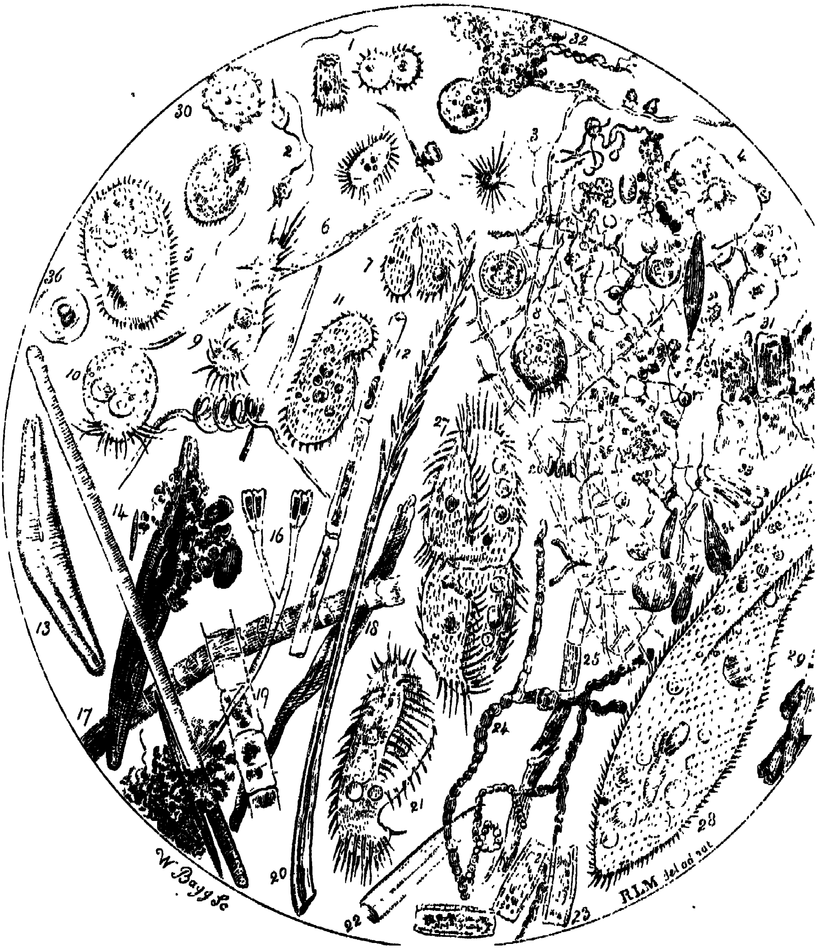
## DESCRIPTION OF PLATE III.

*rawing of Sediment in Thames Water, taken just above Teddington Lock, in April* 1868. *Notice the evidence of impurities from men, viz., epithelium, woollen, cotton, and flax fibres.*

Fig. 1. Coleps hirsutus.
2. Bodo grandis.
3. Actinophrys Eichornii.
4. Epithelium (tessellated).
5. Leucophrys striata.
6. Anguillula fluviatilis.
7. Paramecium chrysalis, dividing (? sexual stage).
8. Vorticella microstoma.
9. Kerona, young ?
10. Vorticella microstoma (stemless).
11. Paramecium aurelia.
12. Conferva.
13. Cocconema lanceolatum.
14. Synedra splendens.
15. Gyrosigma attenuatum.
16. Gomphonema acuminatum.
17. Wool fibre, dyed.
18. Cotton fibre, dyed.
19. Conferva floccosa.
20. Hair, barbed, of ?
21. Kerona mytilus.
22. Siliceous spicule.
23. Diatoma vulgare.
24. Fungi (? Torula).
25. Flax fibre.
26. Arthrodesmus quadricaudatus.
27. Stylonichia ? histrio, dividing.
28. Paramecium caudatum.
29. Woody fibre, ? rootlets.
30. Pollen.
31. Vegetable tissue and mycelium, with spores.
32. Decaying vegetable matter.
33. Gomphonema curvatum.
34. Spores of Fungi (? Aregma).
35. Antherozoid of ?
36. Encysted spore.

Decaying vegetable matter and infusoria abundant.

*(To Binder—To face Plate III.)*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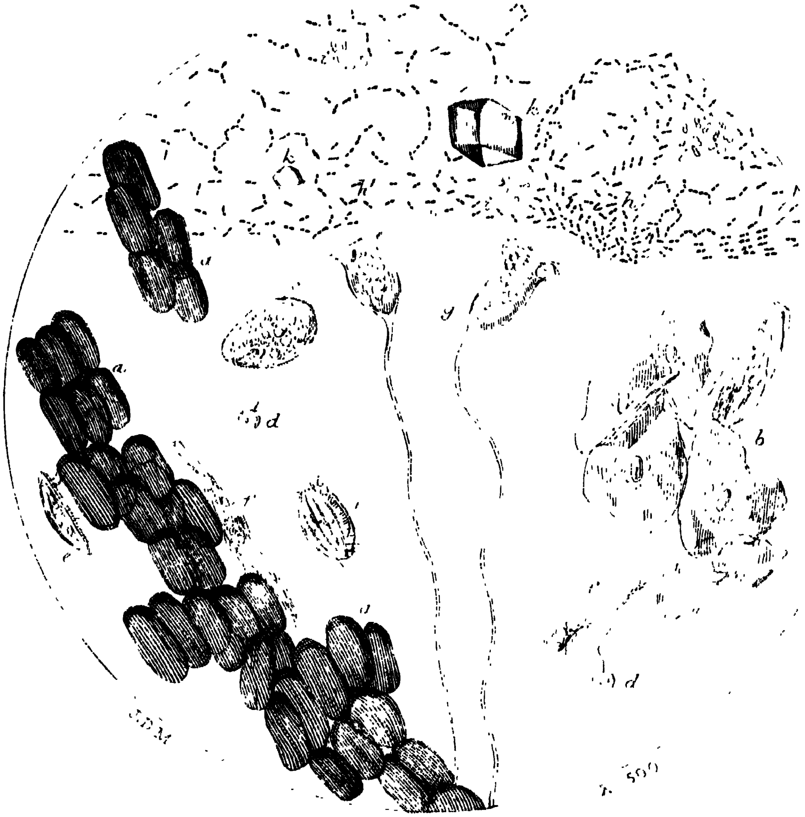

## References

a. a. a Brown Vegetable cells. (probably Sporangial) probably disengaged goni of Lichens (Leighton)
b Scales of Epithelium
c Glaucoma scintillans.
d Monas lens.
e [illegible] articulata, or Surirella
f f' Oxytricha pellio. f' young.
g Vorticella Convallaria
h Bacterium termo in a broad sheet.
h' Localized groups of a larger form.
k. Crystalline particle, probably quartz

1868 above Teddington Lock (Plate III.); in water from a spring near Railway at Tilbury (Plate IV.)

### *Chemical Examination of the Sediment.*

The amount of sediment is told by taking two equal quantities of water (say ½ litre), evaporating one quantity to dryness at once, and the other after subsidence and filtration, so that suspended matters are as far as possible separated, and then weighing the two residues. The difference between the two weights gives the amount of the sediment. Or a certain amount of water may be allowed to stand until all the sediment has fallen; the water is poured off, and the sediment dried and weighed. If good Swedish filtering paper is obtainable, the sediment may be obtained at once; two filters should be moistened with dilute hydrochloric acid, then washed with distilled water and then dried. The amount of ash in one filter should then be determined by incineration; the sediment should be collected on the other filter, dried, weighed, and then incinerated. The ash of the filter itself being known, the weight of the ignited sediment is the total weight, less the ash of the filter. If it be wished to carry the analysis farther, the sediment is incinerated; mineral matter remains, while all animal and vegetable matter, whether previously inanimate or living, is destroyed. This matter of such various origin is generally stated under the vague terms of organic or volatile matter, but this gives no idea of its origin. Some of this so-called organic matter may have been dead; another portion living. The mineral matter may be further determined by digesting in weak hydrochloric acid by the aid of heat; the undissolved matters are silica and silicate of alumina; lime, iron, and magnesia will be dissolved, and can be tested for as hereafter given.

## SUB-SECTION II.

## EXAMINATION OF DISSOLVED MATTERS.

In all examinations of water, if the sediment is not expressly referred to, it is to be understood that the examination refers only to the dissolved matters. These are gases or solids.

*Gases.*—Oxygen, nitrogen, carbonic acid, sulphuretted hydrogen, and carburetted hydrogen are the most usual gases. If the three former co-exist, as is generally the case, the oxygen is usually in larger relative amount than in atmospheric air, as it often reaches 32 per cent. The amounts of oxygen and carbonic acid depend so much on varying conditions, such as the amount of exposure to the air, the growth or absence of plant life, and the presence of animals, as to render the proportions, absolute and relative of the gases, so variable, that few inferences of hygienic importance can be drawn from their determination. A lessening, however, in the quantity of oxygen at one part of its course which a certain water is known to contain, may be useful, as pointing out that organic matter has been in the water.*

Thus Professor Miller found that Thames water contained the following amount or gases in C.C. per litre, in its flow down stream:—

| | Kingston. | Hammersmith. | Somerset House. | Greenwich. | Woolwich. |
|---|---|---|---|---|---|
| Carbonic acid, | 30·3 | ... | 45·2 | 55·6 | 48·3 |
| Oxygen, . | 7·4 | 4·1 | 1·5 | ·25 | ·25. |
| Nitrogen, . | 15 | 15·1 | 16·2 | 15·4 | 14·5 |

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* Up to quite recently Gérardin considered that the degree of oxygen (oxymétrie) was the best test of a water's purity. He has lately modified this view considerably.

The stability of the nitrogen, the increase in the carbonic acid, and the lessening of the oxygen, are well seen. If water contain much carbonic acid bubbles of the gas form on the sides of the glass in which the water is placed.

To determine the quantity of these gases, we require a mercurial trough, a graduated tube-measure to be filled with mercury inverted into the trough, a flask and a connecting tube with a bulb blown on it. The flask is filled with water and connected with the bulb-tube by an india-rubber tube, which is to be closed by a clamp. Some water is put into the bulb, and boiled; this is to expel air from the connecting tube; and when this is done, the end of the tube is put into the mercurial trough under the vessel filled with mercury, the clamp is removed from the india-rubber tube, and the water is cautiously boiled for an hour. The gases collect in the mercurial tube, and are measured (due regard being had to temperature and pressure, and the other corrections); the carbonic acid is absorbed by potash, the oxygen by potassium pyrogallate, and the nitrogen is read as the residue.

As regards the carbonic acid, there is an objection to this method, as the heat decomposes the calcium and magnesium bicarbonates, and therefore the amount of carbonic acid evolved is greater than existed in the water as free carbonic acid. On the other hand, it is impossible by heat alone to obtain all the oxygen and nitrogen.[*]

As this operation is a rather delicate one, and requires some practice, and as the information it gives, in a hygienic point of view, does not appear to be so useful as that obtained by other methods, it may be omitted except in cases where the amount of aeration is considered very important. The amount of free carbonic acid can also be determined approximately by the soap solution subsequently described. Dr Macnamara has directed in his scheme a still simpler method for the examination of water in India.

Dr Frankland has proposed a very ingenious plan for extracting the gases from water without heat. It is an application of the Sprengel pump, in which the Torricellian vacuum of a barometer is made to act as an air-pump. The gases can be extracted either at the ordinary or boiling temperature. It is probable that in laboratories where much water analysis is carried on, this plan will come into general use, but it can hardly at present be applied by army medical officers.

Hydrosulphuric acid sometimes occurs in water from the decomposition of sulphates by organic debris, even by the cork of the bottles, and then liberation of $SH_2$ by carbonic acid. In some mineral waters (Marienbad) sulphuretted hydrogen appears when algæ are in the water, but not without.[†]

If the gas is present in any quantity, it can be detected by the smell. Sulphides have, however, less smell. Both, even without smell, can be detected by salts of lead. A large quantity of water should be taken in an evaporating dish, and a little clear lead subacetate or acetate allowed to flow tranquilly over the surface. Black fibres of lead sulphide are formed. If lead acetate is mixed with solution of soda until the precipitate which at first forms is redissolved, a very delicate test-liquor is obtained. Solution of sodium nitro-prusside is also a delicate test, and gives a beautiful violet-purple colour. As it only acts on the sulphides, a little solution of soda must also be added to detect the free hydrosulphuric acid.

Carburetted hydrogen in small quantity in water is not readily detected, but Tiemann says that warming the water to 110° Fahr., will enable the smell to detect coal-gas, when chemical reagents fail. Generally there are other impurities, especially if it be derived from gas impregnation. In larger quantity it sometimes bubbles up from the water of stagnant pools, particularly if there be much vegetable matter; and in the cases of some natural springs in petroleum districts, can be ignited.

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[*] The plan of determining the oxygen by means of the sodium hydrosulphite, suggested by Schützenberger and Gérardin, is ingenious and rapid, but it has the inconvenience of requiring the reagent to be freshly prepared, as it will not keep. (See Comptes Rendus de l'Académie des Sciences; Lefort, Traité de chimie hydrologique; Annales d'Hygiéne, Janvier, 1877.

[†] Archiv für Wiss. Heilk, 1864, No. III. p. 261.

### *Dissolved Solids.*

The discrepancies which are sometimes found in the consecutive analyses, or in analyses by two observers of the same water, probably arise from the difficulty of always separating the suspended matters. Consequently two samples, apparently similar, may in reality contain variable quantities of suspended matters which affect the determination of the solids, or influence other tests.

To avoid this source of fallacy, the water to be examined, if sedimentous, should be placed in a well-stoppered bottle in a dark place for 24 or 48 hours, until all sediment has subsided, and the clear water should be then syphoned off. If the sediment is too fine to subside, the water must be filtered through paper (previously well washed with weak hydrochloric acid, and then with distilled water, and then dried), but if possible filtration should be avoided.

The chemical examination of the dissolved matters is divided into the qualitative and the quantitative.

### QUALITATIVE EXAMINATION OF DISSOLVED SOLIDS.

The water may be either at once treated, or, in the case of some constituents, it should be concentrated by evaporation.

#### *Water not Concentrated.*

| Substance sought for. | Reagents to be used and effects. | Remarks. |
|---|---|---|
| Reaction | Litmus and turmeric papers; usual red or brown reactions. | Usually neutral. If acid and acidity disappears on boiling, it is due to carbonic acid. If alkaline and disappears on boiling, to ammonia (rare). If permanently alkaline, to sodium carbonate. |
| Lime | Oxalate of ammonium.<br>White precipitate. | Six grains per gallon give turbidity; sixteen grains considerable precipitate. |
| Chlorine | Nitrate of silver, and dilute nitric acid.<br>White precipitate becoming lead colour. | One grain per gallon gives a haze; four grains per gallon give a marked turbidity; ten grains a considerable precipitate. |
| Sulphuric Acid | Chloride of barium and dilute hydrochloric acid.<br>White precipitate. | One-and-a-half grains of sulphate give no precipitate until after standing; three grains give an immediate haze, and, after a time, a slight precipitate. |
| Nitric Acid | Brucine solution[*] and pure sulphuric acid.<br>A pink and yellow zone. | The sulphuric acid should be poured gently down to form a layer under the mixed water and brucine solution; half a grain of nitric acid per gallon gives a marked pink and yellow zone; or, as recommended by Nicholson, 2 C.C. of the water may be evaporated to dryness; a drop of pure sulphuric acid and a minute crystal of brucine be dropped in; ·01 grain per gallon can be easily detected. |

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Brucine solution is made by dissolving one gramme in 1000 C.C. of distilled water. The

### *Water not Concentrated*—continued.

| Substance sought for. | Reagents to be used, and effects. | Remarks. |
|---|---|---|
| Nitric Acid. | Solution of sulphate of iron and pure sulphuric acid.<br>Olive-coloured zone.<br>Solution of pyrogallic acid and pure sulphuric acid.<br>A pink zone turning purple. | Add an equal bulk of pure sulphuric acid to the water, and after cooling pour in gently the iron solution, so as to float above the mixed acid and water.<br>Add to the water and sulphuric acid (prepared as for the Brucine test) a drop or two of the solution of pyrogallic acid (strength about 2½ per cent. slightly acidulated with sulphuric acid.) |
| Nitrous Acid | Iodide of potassium[*] and starch in solution, and dilute sulphuric acid.<br>An immediate blue colour. | Add the solution of iodide of potassium and starch, and then the acid; the blue colour should be immediate; make a comparative experiment with distilled water. |
| Ammonia | Nessler's solution.<br>A yellow colour or a yellow brown precipitate. | If in small quantity, several inches in depth of water should be looked down on a white ground. |
| Iron | Red and yellow prussiates of potash.<br>Blue precipitate. | The red for ferrous and the yellow for ferric salts. |
| Sulphuretted Hydrogen | A salt of lead.<br>Black precipitate. | When the water is heated the smell of sulphuretted hydrogen may be perceptible. |
| Sulphides | Nitroprusside of sodium.<br>A beautiful violet purple colour. | A black precipitate with lead, but no colour with nitroprusside shows that the sulphuretted hydrogen is uncombined. |
| Oxidisable matter, including organic matter. | Gold chloride:—colour varying from rose-pink through violet to olive; a dark violet to black precipitate. | The water, which should be neutral or feebly acid, must be boiled for 20 minutes with the gold chloride. If no nitrous acid be present, the reaction may generally be considered due to organic matter. |
| Do. | Permanganate of potassium.<br>Red colour disappears. | In the absence of nitrites, the reaction indicates organic matter; if action rapid, probably animal; if slow, probably vegetable. |
| Lead or Copper. | Ammonium sulphide. Dark colour, not cleared up by hydrochloric acid. | Place some water (100 C.C.) in a white dish, and stir up with a rod dipped in ammonia sulphide; wait till colour produced, then add a drop or two of hydrochloric acid. If the colour disappears it is due to iron; if not, to lead or copper.[†] |
| Zinc. | Sulphuretted hydrogen. A white precipitate. | This test is not available if there be iron present, should the water be alkaline. It forms, however, in perfectly neutral waters, but not in acid. |

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test may be used in another way: mix a crystal of brucine with a drop of sulphuric acid on a watch glass, and then let a drop of water run down into it.

[*] Iodide of potassium, 1 part; starch, 20 parts; water, 500 parts; make the starch first and filter when cold, and add to the solution of iodide of potassium.

[†] Wanklyn.

### *Water Concentrated to $\frac{1}{50}$th (in a porcelain dish.)*

| Substance sought for. | Reagents to be used, and effects. | Remarks. |
|---|---|---|
| Magnesia | Oxalate of ammonium to precipitate lime, then after filtration a few drops of phosphate of sodium, of chloride of ammonium, and of liq. ammoniæ. A crystalline precipitate in 24 hours. | A precipitate forms in 24 hours, and is the triple phosphate either in the shape of prisms or in feathery crystals. |
| Phosphoric Acid | Molybdate of ammonium and nitric acid.<br>A yellow colour, and on standing a precipitate. | Add the nitric acid, and stir with a glass rod, then add molybdate and boil. |
| Nitric Acid | Brucine and iron tests. | If the nitric acid is in small quantity it may not be detected in the unconcentrated water. |
| Silicic Acid | Evaporate to dryness, moisten with strong hydrochloric acid; after standing, add boiling distilled water; pour off fluid; dry, ignite; repeat the treatment with hydrochloric acid and water; dry, ignite again, and the residue is silica, or silicate of aluminium. | The residue may be weighed, and thus the silica determined quantitatively. A little clay or oxide of iron will be sometimes mixed with it. |
| Lead or Copper | As above. | If quantity be very small. |
| Arsenic | Marsh's or Reinsch's tests. | Water should be rendered alkaline with sodium carbonate before concentration, then acidulated with hydrochloric acid. |
| Zinc | Evaporate to dryness; treat residue with caustic potash or ammonia, filter and test filtrate with sulphuretted hydrogen; a white precipitate falls. | This is necessary if the quantity be small, or if iron be present. |

### *Inferences from the Qualitative Tests.*

Sometimes no time can be given for quantitative determinations, and the qualitative tests are the only means available by which the question so constantly put, whether a water is wholesome, can be in some degree answered.*

If chlorine be present in considerable quantity, it either comes from strata containing chloride of sodium or calcium, from impregnation of sea water, or from admixture of liquid excreta of men and animals. In the first case the water is often also alkaline, from sodium carbonate; there is an absence, or nearly so, of oxidised organic matters, as indicated by nitric and nitrous acid and ammonia, and of organic matter; there is often much sulphuric acid. If it be from calcium chloride, there is a large precipitate with ammonium oxalate after boiling. If the chlorine be from impregnation with sea water, it is often in very large quantity; there is much magnesia, and little evidence of oxidised products from organic matters. If from sewage, the chlorine is marked, and there is coincident evidence of nitric and nitrous acid and ammonia, and sometimes phosphoric acid; and if the contamination be recent, of oxidisable organic matters. A stream fouled by animals or excreta may thus show at different times of the same day different amounts of chlorine, and this, in the absence of rain, will indicate contamination.

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* Kubel and Tiemann rely very greatly on the qualitative tests.

Ammonia is almost always present in small quantity, but if it be in large amount, and be unaccompanied by nitric acid and nitrous acids and chlorine, it probably indicates vegetable impregnation, and perhaps a marsh origin. A large quantity of ammonia in water is always suspicious. If nitrates, &c., be also present, it is more likely to be from animal substances, excreta, &c. Nitrates and nitrites indicate previously existing animal matters, excreta, remains of animals, or other animal substances;[*] but it has not yet been proved that vegetable matters may not furnish nitrates. If nitrites largely exist, it is generally supposed that the contamination is recent. The coincidence of easily oxidised organic matters, of ammonia, and of chlorine in some quantity, would be in favour of an animal origin. If a water gives the test of nitric acid, but not nitrous acid, and very little ammonia, either nitrate of potassium, sodium, or calcium is present, derived from soil impregnated with animal substances at a long anterior date. If nitrites are present at first, and after a few days disappear, this arises from continued oxidation into nitrates; if nitrates disappear, it seems probable this is caused by the action of bacteria, or other low forms of life. Sometimes in such a case nitrites may be formed from the nitrates. Phosphoric acid, if in any marked quantity, indicates origin from phosphatic strata (which is uncommon) or sewage impregnation. Lime in large quantity indicates calcium carbonate if boiling removes the lime, sulphate or chloride if boiling has little effect. Testing for carbonate of lime is important in connection with purification with alum. Sulphuric acid in large quantity, with little lime, indicates sulphate of sodium, and usually much chloride and carbonate of sodium are also present, and on evaporation the water is alkaline. If water acts greatly and rapidly on potassic permanganate, nitrites or sulphuretted hydrogen will probably be found; if not, the rapid action is from organic matter, which is decomposing; probably animal, as vegetable matter acts more slowly. Ferrous salts, which also act on permanganate, are uncommon in drinking waters. Large evidence of nitric acid, with little evidence from permanganate, indicates old contamination; if the permanganate gives large indications, and especially if there be nitrous acid as well as nitric, the impregnation is recent.

*Tabular View of Inferences to be Drawn from Qualitative Examination.*

| Character of Water. | Chlorine. | Oxidisable matter by Gold Chloride. | Nitrates. | Nitrites. | Ammonia. | Sulphates. | Phosphates. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Good . . | Slight. | Slight. | Trace. | Nil. | Nil. | Trace. | Trace. | A pure water. |
| Usable . | Marked to large. | Slight. | Trace or nil. | Nil. | Nil. | Marked. | Trace or nil. | Probably sea-water contamination. |
| Suspicious | Large. | Marked. | Trace. | Trace. | Trace. | Marked. | Marked. | Probable animal contamination. |
| Bad . . | Large. | Large. | Marked. | Marked. | Marked. | Marked. | Marked. | Probably sewage. |
| Suspicious | Slight. | Moderate. | Nil. | Nil. | Large. | Trace. | Marked. | Probably vegetable, marsh ? |
| Usable . | Marked. | Slight. | Marked. | Trace. | Trace. | Trace. | Trace. | Old animal contamination. |

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[*] Dr Frankland has considered these substances as the representatives of 'previous sewage

A water containing any metal (except iron), other than the alkaline and earthy metals, is to be condemned.

A water containing any gas, other than oxygen, nitrogen, or carbonic acid, is to be considered suspicious, and not to be used without boiling or filtration, or both.

## QUANTITATIVE EXAMINATION OF DISSOLVED SOLIDS.

The gases dissolved in the water have been already alluded to. Of the solids in water, some are mineral, and derived from the mineral constituents of the soil, such as lime, magnesia, and part of the chlorine, sulphuric, carbonic, and silicic acids; others are also inorganic, but are derived from the remains of animals or vegetables, by oxidation or solution, or from the atmosphere, as ammonia, nitric acid, nitrous acid, some of the chlorine, sulphuric, and phosphoric acids. Other constituents, derived from numerous sources, are vegetable or animal matters, which are usually unstable, and are undergoing disintegration and oxidation. They may be nitrogenous or not. The composition of these substances is doubtless extremely various; the determination of the total quantity is difficult; the separation of the different kinds from each other, at present, impossible.

The methods by which the quantity of this organic matter (to use its familiar name) can be expressed have been lately much debated, and even now there is *no general agreement*;* nor, at present, is there any plan by

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contamination." In many cases they are so, but it cannot be held that they are always so; any nitrogenous substance, quite apart from sewage, may furnish them, so that the phrase has been objected to, and is better avoided.

* The following plans have been tried at successive times :—

1. The estimation *by ignition of the dried solids.* However useful ignition is as indicating the presence of nitrites, nitrates, or organic matter, the results are very uncertain as regards quantity, owing to the loss of hygrometric water, the decomposition of carbonates, and errors arising in recarbonating, the loss of nitrites and nitrates, and in some cases of chlorine, as well as the destruction of organic matter. Hence "substances driven off by heat," or "volatile substances," is not an equivalent expression for "organic matters."

2. Precipitation by perchloride of iron, weighing, incinerating, and weighing again. The difficulty here is that all the organic matter is not precipitated, and other mineral substances may be.

3. The determination of the nitrogen and carbon in the organic substances. This is the plan proposed by Dr Frankland, who determines the nitrogen in the ammonia, nitric and nitrous acids which may be present, and also that in organic combination, and in this way gets at the nitrogen, which must have formed part of the organic matter ("organic nitrogen"). In the same way the carbon existing other than in the shape of carbonic acid is determined ("organic carbon"). He has proposed a most ingenious and beautiful process, a short account of which the medical officer will find in my Report on Hygiene in the Army Medical Department Blue Book, vol. viii. p. 300. The most recent and best account of the whole process is contained in Sutton's Volumetric Analysis, 3d Ed. p. 291. This plan requires so much apparatus, time, and skill, as to be quite beyond the reach of medical officers, and it would also appear that in the hands of even very able chemists it gives contradictory results; the quantities are in fact so small, and the chances of error so repeated, that in its present form this really beautiful plan seems not adapted for hygienic water analysis. It is also difficult to know what construction should be put on the results; a water containing much non-nitrogenous organic matter may give a very much larger amount of "organic carbon" than a water containing a much smaller amount of nitrogenous matter, and yet be much less hurtful.

4. The determination of the nitrogen of the organic matters (as ammonia) by means of alkaline permanganate of potassium ("albuminoid ammonia"), after all ammonia existing as such in the water has been got rid of. This plan, proposed by Wanklyn and Chapman, has the merit of simplicity and rapidity. It has been objected to by Frankland on the ground that the whole of the nitrogen is not obtained. There is no doubt of this; but Wanklyn affirms that the quantity obtained is constant, and therefore comparison between different waters can be instituted. Thudichum and Dupré, in their work on Wine (p. 262), state that they find the albuminoid ammonia process so accurate for albumen in wine, that they use it in preference to other methods. It must be confessed, I think, that this point has not yet been probed to the bottom, and that especially the relation of the "albuminoid ammonia" to disease produced by the water has not been yet made out. The "albuminoid ammonia" of

which dissolved vegetable may be distinguished from animal matter, except by reference to the microscopic characters of the sediment, to the source of the water, and the coincident inorganic substances.

The quantitative processes which appear, in a hygienic sense, to be most useful are as follow:—

Determination of the following—

1. The dissolved solids.
    (*a*) Total.
    (*b*) Fixed.
    (*c*) Volatile.
2. Chlorine.
3. The hardness. (*a*) Total. (*b*) Fixed. (*c*) Removable.
4. Free or saline ammonia and nitrogenous organic matter.
    (*a*) Free ammonia.
    (*b*) Albuminoid ammonia.
5. Oxidisable matter and products of organic oxidation.
    (*a*) In terms of oxygen required for total oxidisable matter.
    (*b*) In terms of oxygen required for organic matter only.
    (*c*) Nitrous acid.
    (*d*) Nitric acid.
6. Sulphuric acid, silica, iron, and the alkaline chlorides and carbonates may be determined, but are seldom required.

The statement of results is usually given in this country in grains per gallon, or in parts in 10,000 or 100,000; or it may be given in grammes per litre, which is the same as parts per 1000, and by shifting the decimal point to the right, parts per 10,000, 100,000, or per million are obtained. The smaller quantities are conveniently expressed in milligrammes per litre.*

### 1. *Determination of the Dissolved Solids.*

(*a*) *Total solids.*—The remark already made about suspended matters must be attended to; if possible, obtain a clear water by subsidence rather than by filtering through paper. The solids are determined by evaporation. If very

pure potable water has been simply taken as a standard, and the wholesomeness of other waters judged of by reference simply to this. But at the present time it appears to me the best process we have, and (with some reservation as to the precise inferences to be drawn from it) it seems likely to be generally adopted.

5. Estimation of the organic matter in terms of the oxygen required to oxidise it, the permanganate of potassium being the oxidising agent. This process has been much used and much objected to, and some chemists have now given it up. It gives, certainly, only an approximation, requires care, and will only indicate the organic matter capable of oxidation. Yet it gives really useful information, as it often adds additional evidence to Wanklyn's method, and gives some indication as to the old or recent origin of nitric acid and is easy of application. In spite of the opinion expressed against it by Frankland and others, it appears to me very undesirable to discontinue it; and in those cases where, from want of apparatus, the distillation necessary for Wanklyn and Chapman's method cannot be done, it is at present absolutely essential. Kubel and Tiemann reject both Frankland's and Wanklyn's methods as untrustworthy, and trust to modifications of the permanganate process.

* Grammes per litre are converted into grains per gallon by multiplying by 70. Milligrammes per litre, if multiplied by ·07, are brought into grains per gallon. Grains per gallon are converted into parts per 100,000 by dividing by ·7; parts per 100,000 are brought into grains per gallon by multiplying by ·7.

Equivalents of the French weights—

Gramme, = 15·43 grains.
Decigramme, = 1·543 „
Centigramme, = ·1543 „
Milligramne, = ·01543 „
Litre, = 1·764 pints.
Cubic Centimetre, = 16·9 minims,
28·4 C.C., = 1 fluid ounce avoir.

good scales are available, 200 C.C. of the water are sufficient,* if the scales are inferior, 500 or 1000 C.C. of the water must be taken; then evaporate to dryness with a moderate heat, taking care that the water does not boil, else there may be loss from spurting. If the smaller quantity be taken, the whole evaporation may be conducted in one vessel (of platinum if possible); but if the larger amount must be used, the evaporation should be commenced in a large evaporating dish, and the concentrated water and deposit, if any, transferred into a small weighed crucible. The transference demands great care, so that none of the solids shall remain encrusted in the evaporating dish. All the contents of the large dish being transferred, evaporate to complete dryness in an air, water, or steam bath, keeping the heat below 212° Fahr. When the solids appear quite dry, raise the heat (in an air bath) to 260° or 270°, and keep it heated for half an hour to one hour. Weigh as soon as the capsule is cold, as the dried mass may be hygrometric.

Professor Wanklyn advises a very simple form of steam bath. A common two gallon tin can is taken, a perforated cork fitted in the mouth, and a funnel passed through the perforation; the crucible is placed in the funnel, a little roll of paper being placed between the funnel and crucible to let the steam pass. Water is boiled in the tin can.†

Dr Frankland recommends that the heat shall not be carried above 212° Fahr., while some chemists advise a heat of over 300°. At 212° some water may be retained, while at 260° some organic matter may be dissipated; but as there is really loss of organic matter in some cases below 212°, and not much more at 260°, it seems safer to have the heat carried to the latter point, and to be thus sure of perfect dryness.‡

For the same reason (viz., not to cause loss of organic matter or ammoniacal salts) it is best not to add any sodium carbonate, unless there be any magnesium chloride in the water, when a weighed quantity of pure sodium carbonate can be added.

If the heat is only carried to 212°, it should be continued for a long time.

The dried mass should be now weighed and calculated as grammes per litre, or as grains per gallon.

The determination of the total solids is a most important point, and should be very carefully done. It gives a control over the other quantitative determinations, and if erroneous may make the other conclusions wrong.

(*b*) *Fixed solids.* Incinerate the dried solids with as low a heat as possible; watch the process, and note if there be much blackening, or if any fumes can be seen, or any smell be perceived as of burnt horn. A piece of filtering paper dipped in solution of potassium iodide and starch, and then dried, or a piece of ozone paper, should be held over the crucible to detect any nitrous acid which may be given out.

(*c*) *Volatile solids.* The loss on ignition may be stated as "volatile substances." It consists of destructible organic matters, nitrates, nitrites, ammoniacal salts, combined water, combined carbonic acid,§ and sometimes chlorides. The variableness of the composition of the "volatile substances" has led to the disuse of the process by ignition as too uncertain. Combined with other evidence it gives, however, some useful indications. The incinerated solids may be examined for silica and iron, as hereafter noted.

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* Wanklyn recommends a "miniature gallon" of 70 C.C.s, which, he says, evaporates in one hour. This is too small without a delicate balance.

† If the "miniature gallon" be used, Wanklyn recommends an ordinary beaker-glass.

‡ Tiemann recommends 150° to 180° C. equal to 342° to 354° F.

§ This may be restored by adding a little solution of ammonium carbonate and then drying and driving the excess of ammonia.

### 2. *Determination of Chlorine.*

Chlorine may be determined very rapidly by the volumetric method.

Make a solution of pure silver nitrate, by dissolving 17 grammes (one-tenth of an equivalent) in 1 litre of water. Of this solution 1 C.C. = 3·55 milligrammes of chlorine, or 5·85 of sodium chloride.*

Take 100 C.C. of the water to be examined; place it in a white porcelain dish; add enough solution of yellow potassium chromate to make the solution just yellow, drop in the silver nitrate from the burette, and stir after each addition. The red silver chromate which is first formed will disappear as *long as any chlorine is present.* Stop directly the least red tint is permanent. *Multiply the C.C. used by 10, and then by the co-efficient of chlorine, or of sodium chloride if it be assumed that salt only is present.* Neither the solution of silver nor the water must be acid; if the latter is acid, a little sodium carbonate must be added.

*Example.*—In 100 C.C. of water, a few drops of potassium chromate and 1·5 C.C. of silver solution gave a red colour—1·5 × 10 × 3·55 = 53. milligrammes per litre: 53 × 0·07 = 3·71 grains per gallon.

This calculation may be shortly performed by multiplying the actual number of C.C. used by 2·48. The result is grains per gallon.†

If it be reckoned as sodium chloride, the factor should be 4·09. This process is very useful for determining the amount of salt in various articles of food and drink. In water it is extremely so.

### 3. *Hardness.*

Clark's very useful soap test offers a ready mode of determining this in a manner quite sufficient for hygienic and economic purposes.‡ The processes with the soap test may be divided into two headings.

I. The determination of the aggregate earthy salts, and free carbonic acid, as expressed by the term *total hardness.* The aggregate determination can be divided into two kinds of hardness, viz., that which is unaffected and that which is affected by boiling, and these are termed the *permanent* and the *removable hardness.*

II. The determination of the amount of certain constituents, as the lime, magnesia, sulphuric acid, and free carbonic acid. These results are only approximative, especially in the case of the magnesia; but they are very useful, as they give us enough information for hygienic purposes, and are done in a very short time.

*Apparatus required for the Soap Test.*§—Burette, divided into tenths of a cubic centimeter; measure of 50 C.C. or 100 C.C.; stoppered bottles of about 4 ounces capacity.

*Solutions Required.*—1. Standard solution of barium nitrate. The strength of the standard solution is 0·26 grammes of pure barium nitrate to 1 litre of water; of the concentrated solution, ten times this strength, or 2·6 grammes per litre. In English weights these are 18·2 grains per gallon for the standard, or 18·2 grains to 16 ·ounces for the concentrated solution; 1 part of which has to be diluted with 9 parts of water when used.*

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* If 4·788 grammes of nitrate of silver are taken, instead of 17 grammes, and dissolved in 1 litre of water, 1 C.C. will correspond to 1 milligramme of chlorine. This is the strength ordered in Dr Macnamara's scheme, and recommended by Wanklyn. Sutton proposes a solution half the strength and 50 C.C. of water to be used.

† For greater accuracy a correction for colour may be made, by deducting 0·15 grains per gallon from the result as chlorine, or 0·24 as sodium chloride, per gallon.

‡ The soap solution here recommended was suggested by Assistant-Surgeon Nicholson, R.A., who has also given a complete system of analysis based on the soap test, Chemical Journal, December 1862. Clark's solution may, however, be used.

§ MM. Boutron and Boudet, some years ago, made some modifications in the soap test manipulation, and their plan is now commonly followed in the French army, and is termed "Hydrotimétrie." I am indebted to this plan for several adaptations.

2. Solution of Soap. Dissolve a piece of soft potash soap of the Pharmacopœia in equal parts of alcohol and water; filter and graduate. Or rub in a mortar, emplastrum plumbi of the Pharmacopœia with dry potassium carbonate, in the proportions of 150 to 40, or 3¾ to 1; lead carbonate and potassium oleate are formed; dissolve in rectified spirit, filter and graduate.†

*Method of Graduation.*—Take 50 C.C. of the *standard* solution of barium nitrate; put into the shaking bottle, and add to it slowly the soap solution from the finely graduated burette, shaking vigorously after each addition, and placing the bottle on its side. When a thin beady lather, permanent for five minutes, is equally distributed over the whole surface, the process is complete. Read off the amount of soap solution used; if exactly 2·2 C.C. have been used, the solution is correct; if less, the soap solution must be diluted with spirit and water. A simple rule will show how much spirit must be added. Suppose 1·6 C.C. have been used, and that the whole of the unused soap solution which has been made measures 210 C.C., then

$$\text{As } 1{\cdot}6 \ : \ 2{\cdot}2 \ : \ : \ 210 \ : \ x$$
$$x = 288{\cdot}7 \text{ C.C.}$$

The 210 C.C. must then be diluted with spirit and water to 288·7 C.C. The solution should then be tested once more to see that it is quite correct.

To avoid trouble, it is best always to make the soap solution too strong at first.

As the accuracy of all the subsequent processes depends on this graduation, it is necessary to take the greatest care in the operation.

In all cases the glasses, burettes, &c., must be perfectly clean; the least quantity of acid, for example, will destroy the accuracy of the process.

*Rationale of the Process.*—When an alkaline oleate is mixed with pure water, a lather is given almost immediately; but if lime, magnesia, iron, baryta, alumina, or other substances of this kind be present, oleates of these bases are formed, and no lather is given until the earthy bases are thrown down. Free (but not combined) carbonic acid prevents the lather. The soap combines in equivalent proportions with these bases, so that if the soap solution be graduated by a solution of known strength of any kind, it will be of equivalent strength for corresponding solutions of other bases. There are, however, one or two points which render the method less certain. One of these is, that, in the case of magnesia, there is a tendency to form double salts (Playfair and Campbell), so that the determination of magnesia is never so accurate as in the cases of lime or baryta. Carbonic acid appears to unite in equivalent proportions when it is passed through the soap solution; but if it be diffused in water, and then shaken up with the soap solution, two equivalents of the acid unite with one of soap.

It being clearly understood that the soap test is approximative (though really accurate if carefully used), it will be found an extremely convenient plan for medical men, as it demands very little time.

To avoid the repetition of the term tenth of a centimeter, it will be convenient to call each tenth of a centimeter one measure.

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* Solution of calcium chloride, as originally used by Dr Clark, is often recommended, but the Barium nitrate is more convenient.

† Redwood and Wood. By this plan a very pure and unalterable soap solution is obtained.

| | |
|---|---|
| $\frac{1}{10}$ C.C. or 1 measure Soap solution equals in milligrammes | ·14 lime or ·1 calcium.* |
| " " | ·1 magnesia or ·6 magnesium. |
| " " | ·2 anhydrous sulphuric acid $SO_3$, or ·24 $SO_4$. |
| " " | ·25 calcium carbonate. |
| " " | ·34 calcium sulphate. |
| " " | ·21 magnesium carbonate. |
| " " | ·22 carbonic acid $CO_2$, or ·3 $CO_3$. |
| " " | ·115 sodium. |
| " " | ·195 potassium. |
| " " | ·177 chlorine. |
| " " | ·14 iron. |

### *Processes with the Soap Test.*

(*a*) *Determination of the total Hardness of the Water.*—Take 50 C.C. of the filtered water; put it in a small stoppered bottle, and add the soap solution from the burette; shaking it strongly until a thin uniform beady lather spreads over the whole surface without any break. If the lather is permanent for five minutes, the process is complete; if it breaks before that time, add a drop or two more of the solution, and so proceed until a lather be obtained that is permanent for five minutes.

Then read off the number of measures of soap solution used.

From the total number of measures (or tenths of a centimeter) used, deduct two, as that amount is necessary to give a lather with 50 C.C. of the purest water, and this deduction has to be made in all the processes. The soap solution which has been used indicates the hardness due to all the ingredients which can act on it; in most drinking waters there are only lime and magnesian salts, iron, and free carbonic acid.

The amount of this total hardness is, for convenience, usually expressed in this country in the manner proposed by Dr Clark, *i.e.*, though dependent on various causes, it is expressed as equivalent to so much calcium carbonate per gallon, and in Clark's scale 1 grain of calcium carbonate per gallon is called 1 degree of hardness. Express the total hardness, therefore, in degrees of Clark's scale.†

This is done as follows:—

Each 0·1 C.C., or in other words, each *measure*, of our soap solution corresponds to ·25mg. of calcium carbonate. Multiply, therefore, this co-efficient by the number of measures of soap solution used, and the result is the hardness of 50 C.C. of water expressed as calcium carbonate. Then, as we have acted on one-twentieth of a litre, multiply by 20 to give the amount per litre, and then by 0·07 to bring the amount to grains per gallon.

*Example.*—A lather was given with 5·2 C.C., or 52 measures of the soap solution. $(52 - 2) \times ·25 \times 20 \times 0·07 = 17·5$ grains of calcium carbonate per gallon.

Hardness expressed as calcium carbonate = 17°·5 Clark's scale

(viz., 1° = 1 grain of $CaCo_3$ per gallon).

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* The numbers of the metals as well as of the oxides are given, as the custom is becoming general of stating the amount of the metals themselves. So also the sulphuric acid may be stated as $SO_4$ (like chlorine) instead of $SO_3$; this also facilitates a calculation of combinations, if this is desired. For the same reason, the corresponding quantities of chlorine and sodium are given, for the convenience of calculation.

† Hardness is now frequently expressed as parts in 100,000—to convert Clark's degrees into this notation, multiply by 1·43. Conversely degrees per 100,000 may be converted into Clark's degrees, by dividing by 1·43.

The same result (viz., grains per gallon) is obtained if the number of measures (less 2) is multiplied by ·35; thus, 52 measures were used

$$(52 - 2) \times {\cdot}35 = 17{\cdot}5.$$

If the hardness of the water exceeds 80 measures of the soap solution, 25 C.C. of water only should be taken, and 25 C.C. of distilled water added. The result must then be multiplied by 2.

(*b*) *The Permanent or Irremovable Hardness.*—Boil a known quantity briskly for half an hour, and replace the loss by distilled water from time to time, allow to cool in the vessel, which should be corked, and determine hardness in 50 C.C. If distilled water is not procurable, then boil 200 C.C. down to 100; take half the remainder = (100 of unboiled water) and determine hardness.* After deducting 2 measures, divide the number of measures by 2 for the hardness of 50 C.C., and calculate as usual.

By boiling, all carbonic acid is driven off; all calcium carbonate, except about two grains per gallon, is thrown down; the calcium sulphate and chloride are not affected if the evaporation is not carried too far; the magnesium carbonate at first thrown down is re-dissolved as the water cools. If iron is present, most of it is thrown down.

*Example.*—Before boiling, 52 measures, and after boiling 23 measures, of the soap solution were used.

$$(23 - 2) \times {\cdot}25 \times 20 \times 0{\cdot}07 = 7{\cdot}35$$

grains of calcium carbonate per gallon.

(*c*) *Removable Hardness.*—The difference between the total and the permanent hardness is the temporary or removable hardness, which in the example would be 17·5 − 7·35 = 10·15 grains of calcium carbonate per gallon.

The amount of permanent hardness is very important, as it chiefly represents the most objectionable earthy salts—viz., calcium sulphate and chloride, and the magnesian salts. The greater the permanent hardness, the worse is the water. The permanent hardness of a good water should not be greater than 3° or 4° of Clark's scale.

The determination, then, of

1. The total hardness,
2. The permanent or irremovable hardness,
3. The temporary or removable hardness,

will enable us to speak positively as to the hygienic characters of a water, as far as earthy salts are concerned.†

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* If there is much fixed hardness this process is hardly available.

† *Determination of Certain Constituents by Soap.*—In many cases the analysis must end with the above processes; but it may be desirable to carry it farther, and to determine the amount of some ingredients; for example, lime, magnesia, sulphuric acid, carbonic acid.

An approximate estimate can be given of several of these ingredients by the soap test, which is sufficient for hygienic purposes; and any one who has learned to properly determine the hardness of a water, will be able to carry on the process into finer details.

*Lime by the Soap Test.*—Messrs Boutron and Boudet have proposed, after determination of total hardness, to precipitate the lime by ammonium oxalate, and then to determine the hardness again. The difference will be owing to lime removed. The difficulty here is to add enough, and not too much, of ammonium oxalate, which itself in excess gives hardness.

I have found the best way to perform this process is to have a perfectly concentrated clear solution of ammonium oxalate, and to add to 50 C.C. of water 1 drop for every 4 measures of soap solution used; then in other bottles, to add respectively, 1, 2, and 3 drops more. Then determine hardness of all the bottles, and select the result which gives the least hardness. In this way we can hit on the bottle which contains enough, but not too much ammonium oxalate. The water need not be filtered, but it should be allowed to stand at least for three or four hours, or, better still, twenty-four hours, before the hardness is taken.

Then multiply the difference between the total hardness and the hardness after the addition of the oxalate by the co-efficient for lime; this is ·14, as each measure of the soap solution is equivalent to this amount of lime.

*Sulphuric Acid by Soap Test.*—This plan was proposed by Boutron and Boudet, and is briefly as follows:—The hardness of the water being known, 50 C.C. of the standard barytic solution (·26 grammes per litre) are added to 50 C.C. of water, and the mixture is allowed to stand for 24 hours. The hardness (supposing no $SO_4$ were present) would be exactly equal to the original hardness of the water and of the barytic solution combined. But $SO_4$ being present, barium sulphate is precipitated, and there is a loss of hardness. Each degree of loss equals ·24 of sulphuric anhydride ($SO_4$).

| | |
|---|---|
| *Example.*—Original hardness, . . . . . . | 62 |
| 50 C.C. barytic solution . . . . . | 22 |
| | 84 |
| After precipitation, . . . . . . | 71·2 |
| Difference, . . . . | 12·8 |

$$\cdot24 \times 12\cdot8 \times 20 \times 0\cdot07 = 3\cdot584 \text{ grains per gallon of } SO_4.$$

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| | |
|---|---|
| *Example.*—Total hardness, . . . . . | 52 |
| After lime precipitated, . . . . . | 10 |
| Difference, . . . . . | 42 |

$$42 \text{ measures} \times \cdot14 \times 20 \times 0\cdot07 = 8\cdot232 \text{ grains of lime per gallon.}$$

Or, to save trouble, multiply the number of measures by ·196; the result is grains per gallon. If carefully done this result will be near the truth.

*Magnesia by the Soap Test.*—Boutron and Boudet propose to determine the magnesia by boiling the water from which the lime has been thrown down. All usual elements of hardness, except the magnesia, are thus got rid of. This is by no means so accurate a process as that of the lime; the lather is formed much less perfectly and sharply, and in addition the constitution of the magnesia and soap compound is variable. The result must be considered as quite approximative, but may sometimes be rendered more accurate by diluting with distilled water.

Take 200 C.C. of water; add to it the number of drops of solution of ammonium oxalate known to be sufficient by the lime experiment; allow to stand for twenty-four hours; filter, boil for half an hour, replace loss by distilled water; allow to cool in the vessel, which should be well corked, and determine hardness in 50 C.C.

As the lime has been thrown down and all iron removed, and carbonic acid driven off, the hardness is owing to magnesian salts of some kind.

Calculate as magnesia, the co-efficient of which, for each degree of soap solution, is ·1, or, as magnesium, the co-efficient of which is ·06.

*Example.*—Hardness, after [driving off carbonic acid by boiling and precipitating lime = 11.

$$(11-2) \times \cdot1 \times 20 \times 0\cdot07 = 1\cdot26 \text{ grains of magnesia per gallon.}$$

Or, to save trouble, multiply the number of degrees by ·14; the result is grains per gallon.

Although this result is approximative, it is really nearer the truth than the determination by weighing in the hands of a beginner.

*Free Carbonic Acid by the Soap Test.*—In order to get rid of the fallacy from free carbonic acid acting on the soap, Clark recommended that the water should be well shaken in a bottle, so as to disengage some of the $CO_2$, and then that the air should be sucked out. But this does not entirely remove the carbonic acid.

By the soap test the free carbonic acid can be determined in the following way: Throw down all the lime carefully by ammonium oxalate, without adding an excess, and determine the hardness in 50 C.C. as usual. The hardness will be owing to magnesian salts, iron, if it exists (or alumina or baryta in mineral waters), and carbonic acid. If, now, the water, freed from lime, be boiled, and the loss of water replaced by distilled water, the carbonic acid will be driven off. The hardness should be then again determined. The difference between the first and second trials will (if no iron exist in the water) give the amount of soap solution which had been previously acted on by the carbonic acid.

| | |
|---|---|
| *Example.*—1. Total magnesian and carbonic acid hardness, | = 12 measures. |
| 2. Magnesian hardness, . . . . . | = 7 „ |
| Carbonic acid hardness, . . | = 5 „ |

1 measure of soap sol. corresponds to ·22 milligrammes carbonic acid. Therefore,

$$\cdot22 \times 5 \times 20 \times 0\cdot07 = 1\cdot54 \text{ grains per gallon.}$$

As 2·116 cubic inches weigh one grain, multiply the number of grains by 2·116 to bring into cubic inches per gallon.

$$1\cdot54 \times 2\cdot116 = 3\cdot25 \text{ cubic inches.}$$

Usually this process gives good results. Occasionally, from some cause of which I am ignorant, the barium sulphate does not precipitate. This does not depend on the amount of sulphuric acid. The ease with which this process is done renders it useful. The barytic solution is only strong enough to precipitate 6·72 grains of sulphuric acid ($SO_4$) per gallon, so that half the water only must be taken, or less, if the sulphuric acid be evidently in large amount.*

Short factors : for $SO_3 = 0.280$, for $SO_4 = 0{\cdot}336$.

### *Determination of the Earthy and Alkaline Carbonates by Mohr's Process.*

This is a very elegant process, and may be useful.

Prepare a standard solution of sulphuric acid by mixing 4·9 grammes by weight of pure sulphuric acid with distilled water up to one litre; 2 C.C. will saturate 10 milligrammes of calcium carbonate. Prepare a solution of cochineal, by bruising the dried commercial cochineal and digesting it with water, which is gently heated, for a short time. Add a little alcohol and filter.

*Process.*—Take 70 C.C. of the water to examine, and add a drop or two of the cochineal solution, which gives a carmine red colour. Then run in the standard acid solution till the colour becomes yellow or brown-yellow. Read off the number of C.C. used, and multiply by 5. The result is grains of earthy and alkaline carbonates per gallon, stated as calcium carbonate.

*Example.*—70 C.C. of a sample of water, reddened with cochineal, required 3·9 of standard solution to make it yellow :—then $3{\cdot}9 \times 5 = 19{\cdot}5 =$ grains per gallon of earthy and alkaline carbonates as calcium carbonate. If the water be not alkaline to test paper, the result will represent calcium carbonate only.

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Or, to shorten the calculation, multiply the number of degrees of soap solution by ·65 ; the result is the amount of cubic inches per gallon.

$5 \times {\cdot}65 = 3{\cdot}25$ cubic inches per gallon.

If much iron exists in the boiled water, it must be determined and its amount deducted one measure of soap solution corresponds to ·14 grammes of iron (Fe).

*Determination of Lime and Magnesia by Weight.*

It may be desired to determine the lime and magnesia by weight, and the following processes can then be used :—

*Lime by weight.*—Take a known quantity of water ; add ammonium oxalate, and then ammonia enough to give an ammoniacal smell. Allow precipitate thoroughly to subside, and then wash by decantation, or by throwing the precipitate on a small filter of Swedish paper, the weight of the ash of which is known. Decantation is recommended. If a filter is used, wash precipitate on filter ; dry ; scrape precipitate from filter, and place in a platinum crucible ; burn filter to an ash, by holding it in a strong gas flame, and place it also in the crucible. Heat the crucible to gentle redness for fifteen minutes, moisten with a little water, and test with turmeric paper. If no reaction is given, the process is done. If the paper is browned (showing presence of caustic lime), recarbonate with ammonium carbonate, drive off excess of ammonia, dry, and weigh.

The substance weighed is calcium carbonate, multiply by ·56, and the result is lime.

Mohr's plan might also be used, viz. :—precipitation of the lime in an ammoniacal solution by standard oxalic acid, and then titration of the excess of the latter by permanganate.

*Magnesia by weight.*—Take the water from which the lime has been thrown down ; evaporate to a small bulk ; filter if there be turbidity ; add solution of ammonium chloride and ammonia to slight excess ; then add a solution of sodium phosphate ; stir with a glass rod ; set aside for twelve hours ; throw precipitate on a filter, carefully detaching it from the sides of the glass ; wash with ammoniacal water ; dry ; incinerate in an intense heat ; weigh, taking care to deduct the ash of the filter known by previous experiment. The substance is magnesium pyrophosphate ; multiply by ·36036 to get the amount of magnesia.

*Sulphuric Acid.*—Take a known quantity of the water (500 to 1000 C.C.), acidify with hydrochloric acid and evaporate, but not so far as to run any risk of throwing down sulphate of calcium ; filter ; and then add chloride of barium ; allow to stand, and wash the precipitate by decantation ; dry ; weigh ; multiply precipitate by ·34305 to get the amount of sulphuric anhydride ($SO_3$) or by ·411, if it is wished to calculate it as $SO_4$.

* If the amount of $SO_4$ be small, evaporation may be resorted to, or the gravimetric method mentioned above. Wildenstein's method also gives good results. See Sutton's volumetric analysis, 3d edition, p. 97 ; also Report on the progress of Hygiene, Army Medical Reports, Vol. xv. p. 183.

Should the latter be already known (through the hardness), the difference, if any, will represent sodium carbonate, and may be calculated out as such.

### 4. *Determination of Free or Saline Ammonia and Nitrogenous Organic Matter.*

### (*a.*) *Free Ammonia.*

Strictly speaking, ammonia is not derived solely from organic matter, as it is found in the atmosphere. Organic matter passing into water is, however, the chief source, and it seems clear that both vegetable and animal substances will give rise to ammonia.

The very delicate test of ammonia discovered by Nessler* was first applied to quantitative determinations by the late Professor Miller and Mr Hadow, and more recently has been adopted by Dr Frankland, and by Professor Wanklyn and Mr Chapman. It is now very largely used in water analysis, and affords a method of determining several important constituents.

*Preparation of Nessler's Solution.*—Take 50 grammes of potassium iodide, and dissolve in 250 C.C. of distilled water; reserve a small quantity, warm the larger part, and add a strong aqueous solution of corrosive sublimate, until the precipitate ceases to disappear, then add the reserved solution of iodide so as to just dissolve the red precipitate; filter, and add to the filtrate 200 grammes of solid potash dissolved in boiled water. Dilute to 1 litre, and add 5 C.C. of a saturated aqueous solution of mercury bichloride. Allow to subside, decant the clear liquid, and keep it in a dark place.

*Standard Solution of Ammonium Chloride.*—Make a solution of ammonium chloride by dissolving ·0315 grammes in a litre of water; this is equivalent to ·01 gramme of ammonia ($NH_3$) in the litre: in other words, each C.C. will represent ·01 milligramme of ammonia.

Instead of weighing ·0315 grammes, it is best to make a solution of ten times the strength (viz., ·315 per litre = ·1 milligramme of $NH_3$ for 1 C.C.), and to dilute it when required by adding nine parts of water to one of the liquid. If sulphate of ammonia is used instead of chloride, the amount is ·3882 grammes per litre for the *strong* solution (1 C.C. = ·1 milligramme).

*Pure Distilled Water.*—If distilled water is redistilled, and the first portion be rejected, the next portion is usually free from ammonia. Or the water may be distilled from potassium permanganate. A good plan, suggested by Dr J. L. Notter, is to add phosphoric acid to the water before distilling: this fixes the ammonia. Before the test is used, the water should itself be tested with Nessler's solution, and it should be also certain that it contains no organic matter which can furnish ammonia. It should also be free from $CO_2$, which interferes with the sharpness of the reaction.

These solutions being ready, the following process is gone through:—

Place in a retort 250 C.C. of the water to be examined, and 5 C.C. of saturated sodium carbonate solution (although Wanklyn says that this, as a rule, is not necessary). Attach the retort to a Liebig's condenser, and distil off about 120 C.C.; carefully measure the amount of distillate; test a little with Nessler's solution in a test-tube; and, if the colour be not too dark, take 100 C.C. of the distillate and put it into a cylindrical glass vessel, placed upon a white plate or piece of white paper. Add to it 1½ C.C. of Nessler. Put into another similar cylinder as many C.C. of the standard ammonium chloride solution as may be thought necessary (practice soon shows the amount), and fill up to 100 C.C. with pure distilled water: drop in 1½ C.C. of Nessler. If the colours correspond the process is finished, and the amount of ammonium chloride used is read off. If the colours are not the same, add a little more ammonium chloride so long as no haze shows itself,—if it does, then a fresh glass must be taken and another trial made. When the process is completed read off the C.C. of ammonium chloride used, allow for the portion of distillate not used, multiply by 0·01 and [illegible] 4: the result is milligrammes of free ammonia per litre, or parts p[illegible]

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* The brown precipitate produced by Nessler's solution has the composition $NHg_2 I, OH_2$; there are 17 parts of ammonia in 559, so that multiplying the weight of the precipitate by ·03041 (viz., $\frac{17}{559}$) gives the weight of the ammonia.

*Example.*—From 250 C.C. of water 123 we[illegible] C.C. were taken for the experiment; 4·5 C.C. of ammonium chloride solution were required to give the proper colour; then 4·5 × [illegible] × 4 = 0·2214 milligrammes of free ammonia per litre.

Should the colour of the distillate prove too dark, a smaller quantity may be used, and made up to 100 C.C. with distilled [illegible] recommends distilling only 50 C.C., Nesslerising it, and then adding one-third to the result, on the ground that (as he says) three-fourths of the ammonia come off in the first 50 C.C. He also says that with smaller sized apparatus 100 C.C. of water gives satisfactory results. (See "Water Analysis," 4th edition, p. 43).

The use of permanent coloured solutions, corresponding with known amounts of ammonia, has been recommended, and caramel has been tried at Netley. As yet the results have not been very satisfactory. Captain Abney, R.E., F.R.S., has also suggested a graduated prism, filled with weak solution of coffee, for the purpose.

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When a Liebig's condenser cannot be obtained, a flask may be used instead of a retort, and the distillate conveyed to the receiver by a tube of glass (or block tin) passing through a vessel of cold water, which must be renewed from time to time. The tube may be bent in any convenient way so as to expose it to the cooling water as much as possible. Every part of the apparatus must be scrupulously clean and well washed with distilled water. It is well to wash the retort, flask, and glass tubes with dilute sulphuric acid, and then rinse out clean with distilled water. In distilling, the retort should be thrust well into the flame, and the distillation carried on rapidly.

The "free" or "saline ammonia" represents the ammonia combined with carbonic, nitric, or other acids, and also what may be derived from urea, or other easily decomposable substances, if they are present. The limit in good waters is taken at 0·02 milligrammes per litre; in bad waters it often reaches 100 times this and more. (See Wanklyn's "Water Analysis," 4th edition, p. 34 *et. seq.*)

After the distillation of the free ammonia, the residue of the water in the retort is to be used for determining the albuminoid ammonia, to be now described.

### (*b*) *Albuminoid Ammonia.*

The object of this process is to get a measure of the nitrogenous organic matter in water, by breaking it up and converting the nitrogen into ammonia, by means of potassium permanganate in presence of an alkali: the ammonia can be distilled off and estimated as above.

*Process.*—A solution of permanganate of potassium and potash is prepared, by dissolving 8 grammes of permanganate and 200 grammes of solid caustic potash in one litre of water, and boiling thoroughly to expel any ammonia and destroy any nitrogenous matter. 25 C.C. of this solution are added to the residue in the retort, after the distillation of the free ammonia, and about

110 to 120 C.C. distilled off. It is sometimes convenient to add a little pure distilled water to the residue if the first distillation has been carried rather far. Wanklyn recommends successive quantities of 50 C.C. to be distilled off and tested until no more ammonia comes over. Determine the amount of ammonia, as was done in the case of the free ammonia, and state the results in this case as *albuminoid ammonia*. In this distillation there is sometimes a little difficulty caused by "bumping," especially in the case of bad waters: to remedy this it has been recommended to use pieces of tobacco pipe or charcoal.* It is better, however, to dilute the water if it be a bad one, and not to distil too rapidly.

A good deal of controversy has taken place as to the significance of this test, some chemists denying that all the nitrogen is obtained. Wanklyn, however, insists that what is obtained is a constant quantity, and that ten times the ammonia represents fairly accurately the nitrogenous organic matter. Although it may not be perfectly accurate, it seems better adapted for hygienic purposes than Frankland's method, which requires apparatus of a complicated and costly character, besides being liable to wide limits of error. With Wanklyn's process a bad water is not likely to escape detection,—in the words of Hassall, "a bad water will appear bad, and a good water will appear good, although the absolute quantities of organic matter cannot be thus determined." ("Adulterations Detected," 1876, p. 82.)

The standard limit of albuminoid ammonia in good water is 0·08 milligrammes per litre, but Wanklyn thinks anything above 0·05 objectionable if the free ammonia be large. He classifies waters into three classes,† viz.:—*Class I.*, waters of extraordinary organic purity, containing from 0·00 to 0·05 of albuminoid ammonia. *Class II.* comprehends the general drinking-waters of this country, giving from 0·05 to 0·10 of albuminoid ammonia. Such water is safe organically. *Class III.*, the dirty waters, yielding more than 0·10 of albuminoid ammonia. This last seems to be rather too sweeping a statement. Although animal matter is the chief source of albuminoid ammonia, it may be yielded by vegetable as well. Decaying leaves produce it (Parkes), also peat (Dearing, Abel, Thorp, Russell). "Much albuminoid ammonia (which generally comes over slowly), little free ammonia, and almost entire absence of chlorides, is indicative of vegetable contamination." (Wanklyn). In the Leek workhouse persons drinking such a water (free ammonia 0·02, albuminoid 0·34) suffered from diarrhœa. There was only 0·5 grains of chlorine per gallon. In the water of a pond in Perthshire I found: free ammonia 0·36, albuminoid 2·00 milligrammes per litre, and chlorine only 0·62 grains per gallon. This had been used for many years without any bad effects observed. (F. DE C.)

In well-waters in villages there is often a large amount of albuminoid ammonia.‡ Wanklyn found in the Thames at Hampton Court 0·28, at London Bridge at high tide 0·59. Dr Palmer found the tank water in Calcutta to vary according to the time of year and amount of rain, the greatest impurity being in May and June, the hottest and driest time. The tank supplying the Bengal Club showed in November 0·38, in May 0·50 and in June 0·62. The water of the Hooghly, 16 miles above Calcutta, had in December 0·10, in May 0·14, and in June 0·10.

It has sometimes been suggested to distil off at once the *total* ammonia by the process with permanganate and potash. Dr Macnamara mentions that this was done daily in Calcutta for a considerable time, and that "by its use any faulty action in the filtering beds of the municipal water-works was at once detected."

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* Both must be heated to redness immediately before use.

† Water Analysis, 4th ed. p. 34.

‡ For examples, see my Lectures on State Medicine, p. 78, table xii. [F. de C.]

### 5. *Oxidisable Matter in Water.*

The oxidisable matter in water consists of oxidisable organic matter, nitrites, ferrous salts, and sulphuretted hydrogen. The last can be easily recognised by the smell, and got rid of by gently warming the water. Ferrous salts are rare, but, if present, they impart a distinct chalybeate taste to the water if their amount reaches the fifth of a grain of iron per gallon (about 3 milligrammes per litre). Generally their presence may be disregarded. There remain, therefore, the oxidisable organic matter, and nitrous acid as nitrites. For determining these the potassium permanganate is very convenient.

(*a*) *Total Oxidisable Matter in terms of Oxygen required for its Oxidation.*—A solution of potassium permanganate is made by dissolving 0·395 grammes of the crystallised salt in one litre of water. In presence of an acid each C.C. of this solution is capable of yielding 0·1 milligramme of oxygen. To test its accuracy a standard solution of oxalic acid is made by dissolving 0·7875 grammes of crystallised oxalic acid in one litre of water: 100 C.C. acidulated with dilute sulphuric acid, and warmed, should exactly decolorise 100 C.C. of permanganate solution.

*Process.**—Take a convenient quantity of the water to be examined, say 250 C.C.; add 5 C.C. of dilute sulphuric acid (1 to 10); drop in the permanganate solution from a burette until a pink colour is established; warm the water up to 140° Fahr. (60° C.), dropping in more permanganate if the colour disappears; when the temperature reaches 140° Fahr. remove the lamp; continue to drop in permanganate until the colour is permanent for about ten minutes. Then read off the number of C.C. used, multiply by 0·1 to get the milligrammes of oxygen, and by 4 to get the amount per litre.

*Example.*—250 C.C. of water, with 5 C.C. of dilute sulphuric acid, required 3·5 C.C. of permanganate to give a permanent colour; 3·5 × 0·1 × 4 = 1·4 milligrammes of oxygen per litre required for *total* oxidisable matter.†

It must be remembered that this includes both organic matter and nitrous acid. We must now differentiate these.

(*b*) *Organic Oxidisable Matter in terms of Oxygen required for its Oxidation.*—Take 250 C.C. of water to be examined; add ~~5 C.C.~~ of ~~dilute~~ sulphuric acid as above; boil the water briskly for 20 minutes; then allow it to cool down to 140° Fahr. (60° C.); then add the permanganate until a pink colour is established for ten minutes. Calculate out the oxygen as above, stating the result as milligrammes per litre required for oxidisable organic matter, or, shortly, as *organic oxygen.*

The rationale of this process is the driving off of the nitrous acid by boiling with sulphuric acid. It is ascertained that this can be done without decomposition.

(*c*) *Nitrous Acid.*—This can now be determined easily by calculating from the difference between the two preceding processes. Each milligramme of oxygen represents 2·875 milligrammes of nitrous acid; we must therefore multiply the difference by this factor, and the result is nitrous acid in milligrammes per litre.

*Example.*—A sample of water yielded, (by process (*a*), 1·4 milligrammes of oxygen per litre; by process (*b*), 0·75. Then we have 1·40 − 0·75 = 0·65 =

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* As recommended by Dr. Woods, late R. A., Journal of the Chem. Society, 1861.

† If special accuracy is required, a correction for colour may be made, by deducting 0·06 from the result stated as milligrammes of oxygen per litre.

milligrammes of oxygen required for nitrous acid: $0·65 \times 2·875 = 1·87$ milligrammes per litre of nitrous acid ($NO_2$).

Hassall[*] has suggested an improvement on the above process (De Chaumont's), namely, instead of boiling away the nitrous acid, to distil it over and determine it directly in the distillate. Fresenius proposes a somewhat similar plan, only using acetic acid for the distillation, and then sulphuric acid for the subsequent titration. Paul's[†] plan is, to precipitate the organic matter with aluminous chloride and sodium carbonate, evaporate slowly down, decant, add distilled water, and determine with the permanganate in the cold. This is a more tedious process, and does not seem to be more accurate.

One or two precautions are necessary in the permanganate processes. In process (*a*) permanganate must be added to the water from the very commencement, in order not to lose nitrous acid, which may be driven off as the water is being heated. The faintest tinge of colour that can be distinctly seen ought to be accepted, provided it remain for ten minutes. Care must be taken to add the sulphuric acid in every case at the beginning; if this is not done a brown colour is struck which spoils the experiment. Sometimes this colour appears, even after acid is added, and is then probably due to excess of organic matter; dilution with distilled water sometimes remedies this. The water should be freed from sediment by subsidence and decantation. The permanganate acts upon the india-rubber tube of the common burette, therefore it is well always to run off what has been in contact with it before beginning, or to use a burette with a glass stop-cock.

The permanganate process is the only one (except Frankland's) that gives us any measure of the oxidisable organic matter in water, and is, in the present state of our knowledge, indispensable, imperfect though its indications may be. It is certainly an aid to our judgment of the condition of a drinking water, being to Frankland's carbon process something the same as the albuminoid ammonia method is to his nitrogen one. None gives us thoroughly trustworthy information, but for the army or navy medical officer, or any one not provided with a well appointed laboratory, the permanganate process, combined with Wanklyn's, gives as much information as is likely to be got at present, and sufficient for hygienic purposes. It must be remembered that the permanganate does not act upon fatty substances, starch, urea, hippuric acid, creatin, sugar, or gelatine.

### *Action of Permanganate in presence of an Alkali.*

In order to avoid some of the fallacies and inconveniences of the test with acid, F. Schultze[‡] has tried the following plan, which has been slightly modified by Lex. Five or more vessels, each containing 60 C.C. of the water to be examined, are taken, and to each 2 C.C. of thin milk of lime are added, and then 1, 2, 3, 4, 5 C.C. &c., of the permanganate solution (viz., ·395 grammes per litre) are added and left for two hours. At the end of that time some of the samples will be decolorised, others still coloured; if No. 1 and No. 2 are colourless, and No. 3 is coloured, then the amount of permanganate destroyed is between 2 and 3 C.C. As in the cold each equivalent of permanganate only gives off 3 (not 5 atoms) of oxygen, each C.C. corresponds not to ·1, but to ·06 milligrammes of oxygen.[§] It is for this reason that 60

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[*] Adulterations Detected, 1876, p. 84.

[†] Watt's Dictionary of Chemistry Vol, V. p. 1032.

[‡] Roth and Lex, *op. cit.* p. 91.

[§] With sulphuric acid the following is the reaction:—

$$2\,(KMnO_4) + 3(H_2SO_4) = K_2SO_4 + 2(MnSO_4) + 3(H_2O) + O_5$$

without acid the reaction is:

$$2(KMnO_4) + H_2O = 2(MnO_2) + 2(KHO) + O_3.$$

C.C. of water are taken instead of 100, for it is clear that if 1 C.C. of the permanganate solution gives only ·06 milligrammes to 60 C.C., it is the same as ·1 to 100 C.C. of the water. The calculation of the results is thus easy; if, for example, Nos. 1 and 2 are decolorised, while No. 3 is coloured, the amount of oxygen required is between ·2 and ·3 milligrammes for 100 C.C., or 2 and 3 per litre. If 60 C.C. of a water take less than 3 C.C. of the permanganate solution to give it a colour permanent for two hours, Lex considers that it is a good water as far as this test is concerned; if 3 and 4 C.C. are required it is a medium water, and if the 5 C.C. do not give a colour the water is bad.

(*d*) *Nitric Acid.*—The most convenient process for determining this is Wankyln and Chapman's modification of Schulze's process, which consists in converting the nitrogen acids into ammonia. We require caustic soda perfectly free from nitrates (which can only be got by dissolving metallic sodium in pure distilled water, 2 grains to 100 C.C. of distilled water); and sheet aluminium. 100 C.C. of the water to be examined are mixed with an equal bulk of the alkali solution, and a piece of aluminium foil, larger than is capable of dissolving, is placed in it and left for several hours. At the end of the time the liquid is distilled in a small retort and Nesslerised if the ammonia be moderate in amount, or determined by a standard acid solution, if it be large (Wanklyn). In this process the ammonia that comes over is made up of the free or saline ammonia present in the water, and that which results from the reduction of both nitric and nitrous acids. We can apply the necessary corrections if we have ascertained the amount of free ammonia and of nitrous acid by the other processes. Thus, let us suppose that we have found in a sample of water 0·052 of free ammonia, and 1·27 of nitrous acid; dividing the latter number by 2·706 we get the amount of ammonia that would result from the nitrous acid alone,—in this case 0·469. If we obtained by the aluminium process 3·371 of total ammonia, we should have:

$$3{\cdot}371 - 0{\cdot}052 - 0{\cdot}469 = 2{\cdot}850 \text{ ammonia from nitric acid.}$$

To convert this into nitric acid we must multiply by 3·706 for $HNO_3$, by 3·647 for $NO_3$, or by 3·176 for $N_2O_5$; so that in the above case we should have 10·562 of $HNO_3$, or 10·394 of $NO_3$, or 9·052 of $N_2O_5$; all in milligrammes per litre.

6. The determination of *sulphuric acid* has already been referred to (page 80).

*Iron* is seldom required to be determined quantitatively, but it may be done by a colorimetric test (as suggested by Wanklyn). Either the water may be tested directly, or, what is better, the incinerated residue of the solids may be treated with hydrochloric acid, and made up to 100 C.C. with distilled water. A cubic centimeter of solution of ferrocyanide of potassium is added, which will strike a blue colour. A comparative experiment with a standard solution of iron may be made. (See under Alum in Bread.) This is a better process than the permanganate method, which with small quantities of iron gives very uncertain results.

*Silica* may be determined from the incinerated residue, by treating it with strong nitric or hydrochloric acid, evaporating to dryness, and again treating with acid; distilled water (about 50 C.C.) is then added, and a little heat applied till everything soluble is dissolved; the residue is silica, which may be collected on a small filter, ignited and weighed. A number of Indian waters contain considerable quantities of silica, either combined or in the suspended matter.*

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* Dr Nicholson, R.A., has noticed that the water at Kamptee, both from the river and from

*Lead, Copper, Arsenic, Zinc.*—The mere presence of these metals is enough to condemn a water, therefore it will seldom be necessary to determine them quantitatively.

### *Inferences from the Quantitative Tests.*

The conclusions to be drawn from the qualitative tests (page 72) hold good for the quantitative, only greater precision is given. It is necessary not to be satisfied with a single test, but to collate the evidence derived from several. For example, a large quantity of nitric and nitrous acids with much oxidisable and nitrogenous organic matter, and much chlorine, show recent sewage impregnation; while a large amount of nitric acid and little oxidisable organic matter show that more or less complete conversion of organic matter has taken place. Much albuminoid ammonia and nitric acid, with little free ammonia and little chlorine, show vegetable impregnation; whilst much albuminoid and free ammonia, nitric and nitrous acids, with little chlorine, show contamination by gaseous emanations. The determination of the chlorine is especially important, as it is done so rapidly and accurately that it affords a good test of alterations in the water; and if at every station this quantitative test were frequently done, and the qualitative tests were also noted, the entrance of sewage or other impure matters containing chlorine would be easily detected. Next to the chlorine the varying amounts of free ammonia, as tested without distillation, where it can be done, would give useful indications, with a very little expenditure of time, provided the amount usually present in the water was known. The water, not only of streams, but of shallow wells, is much influenced in composition by rain, and this has to be taken into account. In all cases the microscopic conditions ought to be carefully noted, when possible, and considered in drawing deductions from the chemical results. It is of great importance that water should be examined, when it can be done, on the spot where it is obtained. At all events the fullest possible information about its source and surroundings should be got before giving an opinion based on the examination.

### *General Statement of the Results of the Water Analysis.**

The analysis can be stated in any convenient form, and the quantities given in grains per gallon or in milligrammes per litre.

The following is the Form of Report at present used at Netley:—

### *Report on a sample of Drinking-water.*

Drawn......................187
from.............................. Received....................187
Source..........................................................
...................................................................

*Physical Characters.*

Colour (*through* 18 *inches*).............. Lustre................................
Turbidity.................................. Taste..................................
Sediment.................................. Smell..................................

---

wells, contains from 2 to 6 grains per gallon of silica derived from micaceous gravel; it is combined with magnesia, and it renders the soap test inapplicable.

[*] For details of further processes reference may be made to Sutton's Volumetric Analysis, 3d edition; Wanklyn's Water Analysis, 4th edition; or Hassall's Adulteration Detected, 1876.

### *CHEMICAL ANALYSIS.*

*Qualitative.*

Lime..............................
Magnesia ..............................
Chlorine ..............................
Sulphuric acid ..............................
Phosphoric acid..............................
Lead or copper..............................
Ammonia ..............................
Nitric acid ..............................
Nitrous acid ..............................
Organic matter ..............................
Iron ..............................
Zinc ..............................

*Hardness.* Total.............................................. Degrees of Clark's scale.
Fixed ..............................................
Temporary or Removable..............................................

*Quantitative.* *grains per gallon.*

Volatile matter [by incineration and after recarbonating] ..............................
Including
Oxygen required for organic matter.............................. milli- grammes per litre.
Ammonia, free ..............................
Do., albuminoid ..............................
Nitric acid..............................
Nitrous acid ..............................
Chlorine..............................
Sodium (combined with do.) ..............................
Calcium carbonate..............................
Fixed hard salts (estimated as calcium carbonate) ..............................
*Sulphuric acid ..............................
*Alkaline carbonates, &c. ..............................
*Silica, Alumina, &c..............................
Total solids by evaporation..............................

*Microscopic characters and remarks.* ..............................

### *Examination of Water suspected to be contaminated with the discharges from Cholera or Typhoid Patients, or with Marsh Water.*

The examination of water contaminated with cholera discharges is a most difficult process. If choleraic stools are added in some quantity the water becomes distinctly hazy, and in places where cholera prevails anything like decided haze should lead to the disuse of the water. If, however, the choleraic discharge is in small amount, the transparency of the water may be unchanged, and in this case it is certain that no chemical test would detect what might be a sufficient amount of cholera poison to cause the disease. Fortunately we have a microscopic test of value. Dr C. Macnamara† has stated that in water contaminated with cholera discharges vibriones appear with great rapidity, and the water is dangerous during this period of active vibrional growth. This observation, made by a careful observer, should certainly be attended to; the water should be carefully examined for vibriones with high powers (1000 to 1200 diameters), and if they are present should be at once rejected. Pasteur's fluid may also be used, and would probably become turbid in a very short time, and this might be an additional test. When the vibrional stage is replaced by the appearance of ciliated infusoria, the water, according to Macnamara, is no longer dangerous.

In the case of the discharges of enteric fever entering water, the amount of the discharge is usually large, and the water is rendered perceptibly foul to smell and taste; chemical evidence of sewage (excess of ammonia, chlorine, phosphoric acid, and oxidisable matters) seems to be usually attainable. Although no observation has been made on the point, it seems likely that, as vibriones exist in great number in the typhoid stools, they would, as in the case of cholera, be found in the water.

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* When these constituents have not been determined in detail, they can be grouped together under the head of "other substances."

† On Asiatic Cholera, 1870, pp. 330 and 397.

In the case of marsh water, again, there is always abundance of vegetable and animal life, and in heating the water the peculiar marshy smell may often be perceived. Tiemann notices that phosphoric acid is sometimes found in large quantities in water from marshy meadows.

## SECTION VI.

### SUB-SECTION I.—SEARCH AFTER WATER.

Occasionally a medical officer may be in a position in which he has to search for water. Few precise rules can be laid down.

On a plain, the depth at which water will be found will depend on the permeability of the soil, and the depth at which hard rock or clay will hold up water. The plain should be well surveyed; and if any part seems below the general level, a well should be sunk, or trials made with Norton's tube-wells. The part most covered with herbage is likely to have the water nearest the surface. On a dry sandy plain, morning mists or swarms of insects are said sometimes to mark water below. Near the sea, water is generally found; even close to the sea it may be fresh, if a large body of fresh water flowing from higher ground holds back the salt water. But usually wells sunks near the sea are brackish; and it is necessary to sink several, passing farther and farther inland, till the point is reached where the fresh water has the predominance.

Among the hills the search for water is easier. The hills store up water, which runs off into plains at their feet. Wells should be sunk at the foot of hills, not on a spur, but, if possible, at the lowest point; and if there are any indications of a water-course, as near there as possible. In the valleys among hills, the junction of two long valleys will, especially if there is any narrowing, generally give water. The outlet of the longest valleys should be chosen, and if there is any trace of the junction of two water-courses, the well should be sunk at their union. In a long valley with a contraction, water should be sought for on the mountain side of the contraction. In digging at the side of a valley, the side with the highest hills should be chosen.

Before commencing to dig, the country should be as carefully looked over as time and opportunity permit, and the dip of the strata made out, if possible. A little search will sometimes show which is the direction of fall from high grounds or a water-shed.

If moist ground only is reached, the insertion of a tube, pierced with holes, deep in the moist ground, will sometimes cause a good deal of water to be collected. Norton's American tube well (page 7) gave satisfaction in Abyssinia, although it did not succeed so well in Ashantee. A common pump will raise the water in it if the depth be not more than 24 or 26 feet; if deeper, a special force pump has to be used.

### SUB-SECTION II.—SPECIAL CONSIDERATIONS ON THE SUPPLY OF WATER TO SOLDIERS.

In barracks and hospitals, and in all usual stations, all that has to be done

During marches each soldier carries a water-bottle. He should be taught to re-fill it with good water whenever practicable; a little flannel bag, into which charcoal may be sewn, can be placed at the opening so as to strain the water.* If the water is decidedly bad, it should be boiled with tea, and the cold tea drunk. The exhausted leaves, if well boiled in water, will give up a little more tannin and colouring matter and will have a good effect; and if a soldier would do this after his evening meal, the water would be ready for the next day's march. Alum and charcoal should be used. Small charcoal or sandstone filters with elastic tubes (fig. 4.) at the top, which draw water through like siphons, or through which water can be sucked, are extremely useful, and are now much employed by officers. They have been largely used by the French soldiers in Algiers. The Austrian soldiers were formerly supplied with two boards pierced with holes, and with compressed sponges between them, and they poured their water through this. They also used sandstone and pumice-stones.

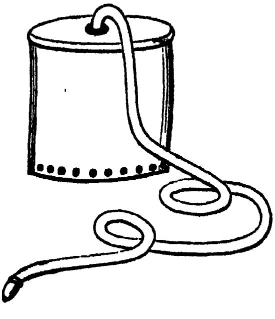

Fig. 4.

Soldiers should be taught that there is danger in drinking turbid water, as they will often do when they are overcome with thirst. Not only all sorts of suspended matters may be gulped down, but even animals. On some occasions, the French army in Algiers has suffered from the men swallowing small leeches, which brought on dangerous bleeding. The leeches which are so small as to look merely like small bits of vegetable matter, fixed in the pharynx, the posterior nares, &c., more rarely in the larynx, causing repeated hæmoptysis, epistaxis, or asphyxia.

If water-carts or water-sacks are used, they should be regularly inspected; every cart should have a straining filter of pure sand, through which the water should pass. The carts and skins should be scrupulously clean. The water-carriers, or bheesties, in India should be paraded every morning, and the sources of water inquired into.

When halting ground is reached, it may be necessary to filter the water. A common plan is to carry a cask, charred inside, and pierced with small holes at the bottom; it is sunk in a small stream, and the water rises through the holes. A better plan still is to have two casks, one inside the other; the

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* I have proposed for adoption into the service a water-bottle with two openings; the larger is provided with a flannel bag, into which, if necessary, a little bit of sponge can be placed, and thus all the coarser suspended matter arrested; a good screw closes this opening; the smaller is used for drinking, and is closed by a plug secured by a little chain. (The Italian water-bottle

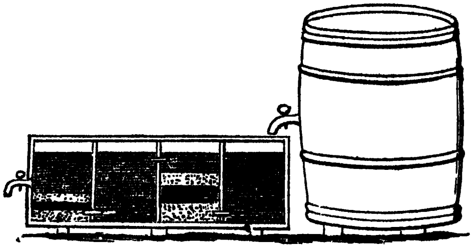

Fig. 5.

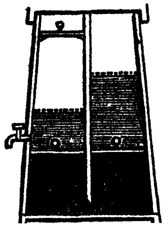

Fig. 6.

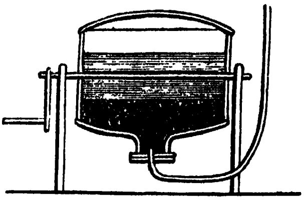

Fig. 7.

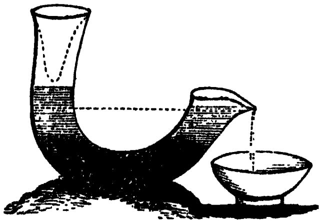

Fig. 8.

outer pierced with holes at the bottom, and the inner near the top; the space between is filled with sand, gravel, or charcoal, if procurable; the water rises

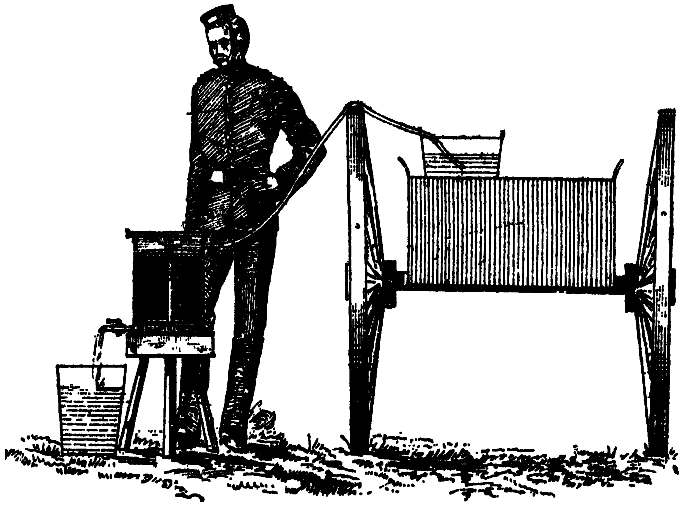

Fig. 9.

through the gravel between the barrels, and flows into the inner barrel. In the French army it is ordered † that, if other means cannot be procured, fresh and inodorous straw be taken, and chopped fine, and pressed at the bottom of a tube pierced with holes; if possible, charcoal is to be intercalated among the straw. Great care must be taken to have the straw pure, and to change it often. Other simple plans are given in the drawings, which need little description. Figs. 5 and 6 speak for themselves. Fig. 7 is a barrel connected by a pipe with a supply above; the water rises through sand and charcoal, and is drawn out above; the barrel is fixed on a winch, and the supply pipe being removed, and the hole closed, a few turns of the handle clear the sand. Fig. 8 is a simple contrivance, which may be made of wood or tin. Figs. 9 and 10 show Crease's field filter in use, either as a hand filter (fig. 10) or connected by an india-rubber tube to a bucket of unfiltered water placed in a cart (fig. 9). It acts with great rapidity and gives good results.

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† Code des Officiers de Santé. Par Didiot. P. 515.

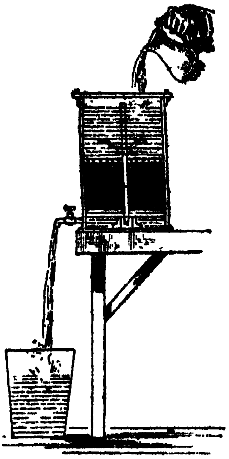

Fig. 10.

In the field, the medical officer may be sent on to give a report of the quantity and quality of any source. Before the troops arrive he should make his arrangements for the different places of supply; men and cattle should be watered at different points; places should be assigned for washing; and if removal of excreta by water be attempted, the excreta should flow in far below any possible spring; in the case of a spring, several reservoirs of wood should be made, and the water allowed to flow from one to another—the highest for men, the second for cattle. If it is a running stream, localities should be fixed for the special purpose; that for the men's drinking-water should be highest up the stream, for animals below, washing lowest; sentries should be placed as soon as possible. The distribution of water should be regulated; streams are soon stirred up, made turbid, and the water becomes undrinkable for want, perhaps, of simple management.

Wherever practicable, the reservoirs or cisterns which are made should be covered in; even if it is merely the most flimsy covering, it is better than nothing.

In sieges the same general rules must be attended to. The distribution of the water should be under the care of a vigilant medical officer. Advantage should be taken of every rainfall; fresh wells should be dug early; if necessary, distillation of brackish or sea-water must be had recourse to.

# CHAPTER II.

# AIR.

It might be inferred from the physiological evidence of the paramount importance of proper aeration of the blood, that the breathing of air rendered impure from any cause is hurtful, and that the highest degree of health is only possible when to the other conditions is added that of a proper supply of pure air. Experience strengthens this inference. Statistical inquiries on mortality prove beyond a doubt that of the causes of death which usually are in action, impurity of the air is the most important. Individual observations confirm this. No one who has paid any attention to the condition of health, and the recovery from disease of those persons who fall under his observation, can doubt that impurity of the air marvellously affects the first, and influences, and sometimes even regulates, the second. The average mortality in this country increases tolerably regularly with density of population. Density of population usually implies poverty and insufficient food, and unhealthy work; but its main concomitant condition is impurity of air from overcrowding, deficiency of cleanliness, and imperfect removal of excreta, and when this condition is removed, a very dense and poor population may be perfectly healthy. The same evidence of the effect of pure and impure air on health and mortality is still more strikingly shown by horses; for in that case the question is more simple on account of the absolute similarity in different periods or places of food, water, exercise, and treatment. Formerly, in the French army, the mortality among the horses was enormous. Rossignol[*] states that, previous to 1836, the mortality of the French cavalry horses varied from 180 to 197 per 1000 per annum. The enlargement of the stables, and the "increased quantity of the ration of air," reduced the loss in the next ten years to 68 per 1000.[†] In the Italian war of 1859, M. Moulin, the chief veterinary surgeon, kept 10,000 horses many months in barracks open to the external air in place of closed stables. Scarcely any horses were sick, and only one case of glanders occurred.[‡]

In the English cavalry (and in English racing stables) the same facts are well known. Wilkinson[§] informs us that the annual mortality of cavalry horses (which was formerly great) is now reduced to 20 per 1000, of which one-half is from accidents and incurable diseases. Glanders and farcy have almost disappeared, and if a case occurs, it is considered evidence of neglect.

The food, exercise, and general treatment being the same, this result has been obtained by cleanliness, dryness, and the freest ventilation. The ventilation is threefold—ground ventilation, for drying the floors; ceiling ventilation, for discharge of foul air; and supply of air beneath the horses' noses, to dilute at once the products of respiration.

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[*] Traité d'Hygiène Militaire. Paris, 1857.

[†] Wilkinson, Journal of the Royal Agricultural Society, No. 50, p. 91, *et seq.*

[‡] Larrey, Hygiène des Hôp. Mil. 1862, p. 63.

[§] *Op. cit.*

In cow-houses and kennels similar facts are well known; disease and health are in the direct proportion of foul and pure air.

The air may affect health by variations in the amount or condition of its normal constituents, by differences in physical properties, or by the presence of impurities. While the immense effect of impure air cannot be for a moment doubted, it is not always easy to assign to each impurity its definite action. The inquiry is, in fact, in its infancy; it is difficult, and demands a more searching analysis than has been, or perhaps than can be at present, given. When impure air does not produce any very striking disease, its injurious effects may be overlooked. The evidences of injury to health from impure air are found in a larger proportion of ill health—*i.e.*, of days lost from sickness in the year—than under other circumstances; an increase in the severity of many diseases, which, though not caused, are influenced by impure air; and a higher rate of mortality, especially among children, whose delicate frames always give us the best test of the effect both of food and air. In many cases accurate statistical inquiries on a large scale can alone prove what may be in reality a serious depreciation of public health.

The quantity of air necessary for perfect health will be considered in the chapter on Ventilation. I shall in the present chapter enumerate the impurities, and then the diseases attributable to them.

It would be occupying unnecessary space to enlarge on the composition of pure air. In addition to oxygen and nitrogen, there are the following substances:—carbonic acid, watery vapour, organic matter in the form probably both of dead and living structures. Perhaps, also, the almost universally diffused salts of soda should be reckoned as normal constituents. The amount of oxygen is about 20·96 in the usual air, 20·98 in the pure mountain air, while in the air of towns, it may fall to 20·90 or 20·87 (A. Smith, "Air and Rain," pp. 35, *et seq.*). The subject of ozone is treated in the chapter on climate.

The amount of watery vapour varies in different countries greatly, from about 40 per cent. of saturation to perfect saturation; or, according to temperature, from 1 to 11, or even 12 grains in a cubic foot of air, if that expression may be admitted. The best amount for health has not been determined, but it has been supposed it should be from 65 to 75 per cent.; but in many healthy climates it is much more than this.

The amount of carbonic acid in normal air ranges from ·2 to ·5 per thousand (or from 2 to 5 volumes in 10,000); it increases slightly up to 11,000 feet of elevation, then decreases; it is slightly augmented under certain circumstances; as in sea air by day, though not at night; the difference being between ·54 to ·33 per thousand (Lewy). During the Arctic Expedition of 1875, Dr E. L. Moss, of the "Alert," found it to range from 0·483 to 0·641 per thousand; mean, 0·552* in N. Lat. 82° 27′.

The normal amount of organic matter is not known, if indeed it is not to be considered as an impurity.

## SECTION I.

## IMPURITIES IN AIR.

A vast number of substances, vapours, gases, or solid particles, continually pass into the atmosphere. Many of these substances can be detected neither by smell nor taste, and are inhaled without any knowledge on the part of those who breathe them. Others are smelt or tasted at first; but in a short time, if the substance remains in the atmosphere, the nerves lose their delicacy; so that, in many cases, no warning, and in other instances, slight warning only, is given by the senses of these atmospheric impurities.

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* Dr B. Ninnis of the "Discovery," found much higher amounts, but the conditions may not have been quite the same, or some accidental error may have occurred. (See Report of the Committee on the Outbreak of Scurvy, 1877.)

As if to compensate for this, a wonderful series of processes goes on in the atmosphere, or on the earth, which keeps the air in a state of purity.

Gases diffuse, and are carried away by winds, and thus become so diluted as to be innocuous; or are decomposed if compound, or are washed down by rain; solid substances lifted into the air by winds, or by the ascensional force of evaporation, fall by their own weight; or if organic, are oxidised into simple compounds, such as water, carbonic acid, nitric acid, and ammonia; or dry and break up into impalpable particles, which are washed down by rain. Diffusion, dilution by winds, oxidation, and the fall of rain, are the great purifiers; and in addition, there is the wonderful laboratory of the vegetable world, which keeps the carbonic acid of the atmosphere within certain limits. If it were not for these counterbalancing agencies, the atmosphere would soon become too impure for the human race. As it is, it is wonderful how soon the immense impurity, which daily passes into the air, is removed, except when the perverse ingenuity of man opposes some obstacle, or makes too great a demand even upon the purifying powers of Nature.

The air passing into the lungs in the necessary and automatic process of respiration, is drawn successively through the mouth and nose, the fauces, and the air tubes. It may consist, according to circumstances, of matters perfectly gaseous (as in pure air), or of a mixture of gases and solid particles, mineral or organic, which have passed into the atmosphere.

The truly gaseous substances will doubtless enter the passages of the lungs, and will meet there with that wonderful surface, covered with the most delicate tufts of blood-vessels, unshielded even, it is supposed by some, by epithelium, which stand up on the surface of 5,000,000 or 6,000,000 air-cells, and through which the blood flows with great velocity; there they will be absorbed, and if, as has been calculated, the surface of the air-cells is as much as from 10 to 20 square feet (and some have placed these figures much higher), we can well understand the ease and rapidity with which gaseous substances will enter the blood.

The solid particles or molecules entering with the air, may lodge in the mouth or nose, or may pass into the lungs,* and there decompose, if of destructible nature; or may dissolve or break down if of mineral formation; or may remain as sources of irritation until dislodged; or perhaps become covered over with epithelium, like the particles of carbon in the miner's lung, or may pass into epithelium and enter the body through the lymphatics.

If such particles lodge in the mouth or nose they may be swallowed, and pass into the alimentary canal, and it is even more probable that this should be the case with all except the lightest and most finely divided substances, than that they should pass into the lungs. Although incapable of present proof, there is some reason to think that some of the specific poisons, which float about in an impure atmosphere, such as those which arise from the typhoid or cholera evacuations, may produce their first effects, not on the lungs or blood, but on the alimentary mucous membrane, with which they are brought into contact when swallowed.

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* The evidence of "miners' phthisis" proves this; but in addition, Professor Zenker has published cases in which snuff and different coloured powders have been found in the lungs of workmen employed in workshops in which such particles have been mixed with air. Dr Knauff (Virchow's Archiv, band 39, p. 442) confined animals in a box into which the particles of a sooty lamp passed; the animals were well fed and were healthy; the charcoal passed into the lungs, and was got rid of by expectoration in the form of pigment-cells. When Knauff inhaled particles of ultramarine for only ten minutes, and examined his sputa, he found cells with blue particles in their interior. In a cat charcoal particles penetrated in three days from the lungs into the lymphatic glands and to the pleura.

Dr Greenhow (Trans. Pathol. Society, 1868–69) has also pointed out how easily small floating particles enter the air-cells, and encroach on the alveoli, and pass into the interior of ciliated epithelium. Villaret confined rabbits in a smoky atmosphere and proved the existence of fine particles of carbon in the bronchi. Franke (Deutsche Klinik, 1860, No. 49) found particles of charcoal in the lungs in a man employed in loading charcoal.

## SUB-SECTION I.—SUSPENDED MATTERS.

*Nature of Suspended Substances.*—An immense number of substances, organic and inorganic, may be suspended in the atmosphere. From soil the winds lift silica, finely powdered silicate of alumina, carbonate and phosphate of calcium, and peroxide of iron. Volcanoes throw up fine particles of carbon, sand, and dried mud, which passing into the higher regions, may be carried over hundreds of miles.

The animal kingdom is represented by the *débris* of the perished creatures who have lived in the atmosphere, and also it would appear that the ascensional force of evaporation will lift even animals of some magnitude from the surface of marsh water. The germs, also, of Vibriones, Bacteria, and Monads (if we may call these animals), are largely present, and small eggs of various kinds.

From the vegetable world pass up seeds and *débris* of vegetation; pollen, spores of fungi, mycoderms, mucedines, which may grow in the atmosphere, and innumerable volatile substances or odours.

From the sea the wind lifts spray, and the chloride of sodium becoming dried is so diffused through the atmosphere, that it is difficult, on spectrum analysis, to find a spectrum without the yellow line of soda.

The works and habitations of man, however, furnish matters probably of much greater importance in a hygienic point of view.

It is not easy at present to give a complete enumeration of all the substances, but the following are the chief facts, divided under the headings of suspended substances in the external air; in rooms inhabited by healthy persons; in rooms inhabited by sick persons; in workshops and factories.

### *Suspended Substances in External Air.*

1. Dust and sand showers. In different parts of Europe there occur from time to time showers of dust and sand. Ehrenberg* gives the microscopic examination of seventy showers; in addition to particles of sand and oxide of iron there were numerous organic forms, which are classed by Ehrenberg under the headings of polygastrica (194 forms), phytolithariæ (145 forms), polythalmia, &c. In addition there were portions of plants and fragments of insects. In a dust storm of February 1872, in Sicily, Silvestri † found four species of diatoms and living infusoria. These sand-storms are sometimes called monsoon showers, but it would appear that any violent storm of a cyclonic character may lift the dust from sandy wastes, as from the African deserts, and transport it great distances.

It remains yet uncertain whether all dust-storms are entirely of telluric origin; it has been supposed that some may be derived from meteoric showers,

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* Ehrenberg's latest work was published in 1871. Uebersicht der, seit 1847, fortgesetzten Untersuchungen über das von der Atmosphere unsichtbar getragene reiche organische Leben. Berlin, 1871.

† Comptes Rendus, 1872, avid, p. 991.

*i.e.*, may enter our atmosphere from the realms of space, and there has been some speculation as to whether morpholithes of peculiar nature may not be contained in such meteoric dust showers. But the point at present has not been cleared up.

There seems no doubt that atmospheric dust may travel to great distances; the air of Berlin has evidently contained organisms derived from the African deserts, and the sails of ships 600 or 800 miles from Africa are often quite red with the sand which lodges on them.

2. Independent of these sand-storms there are numerous living creatures in the atmosphere: some lifted from the ground by winds, others growing in the air. Ehrenberg has discovered at least 200 forms—rhizopods, tardigrades, and anguillulæ. These can be dried, and will then retain their vitality for months, and even years.

When the external air is examined, either by means of an aeroscope of some kind, or by drawing it through previously heated glass tubes, surrounded by a freezing mixture, many of these organisms can be found. Their number cannot be directly estimated at present. Indirectly A. Smith has endeavoured to calculate the amount[*] from the ammonia in the air which appears to be derived from organic matter, and has supposed that there might be 529,560 germs (= ·0056 grain) in one cubic foot of the air of a city. But indirect calculations of this kind are of course doubtful. The following are the most important kinds:—

(*a*) Extremely small round and oval cells, sometimes growing together, or more probably cleaving, and then presenting an appearance like the figure of 8. The cells, described by Lemaire,[†] Trautman,[‡] Béchamp, and others, are exceedingly minute, and it requires a power of 600 to 1000 diameters to see them properly. Trautman states that they grow faster when sulphuretted hydrogen is in the air, and are checked by carbolic acid. Lemaire found them in immense quantities in the air of dirty prison cells, and in the sweat of the prisoners; they will occur, however, in the open air. They are supposed to increase rapidly by cleavage, but their future development, if any, has not been traced; no effect on the body has been proved to be produced by them. To these bodies the term microzymes should perhaps be restricted.

To the same class, perhaps, as those round and oval cells, the bacteria and monads, which have been described as gathered from the air, must be assigned; the development of these cells into moving vibriones and rod-like bacteria, though asserted, has not yet been definitely proved, and indeed Burdon-Sanderson's observations rather throw doubt on the statement that true bacteria exist in the air. Dr D. D. Cunningham[§] found that Bacteria are rarely present (that is, recognisable,) in dry atmospheric dust, but they were occasionally found, as well as a specimen of green spirillum. But in the deposit from the moist air of sewers distinct Bacteria were frequently observed.

(*b*) Spores of fungi are not infrequent; in the open air they occur most commonly in the summer (July and August [||]); they are not in this country more frequent with one wind than another; the largest number found by Maddox in ten hours was 250 spores; on some days not a spore can be found. Maddox leaves undetermined the kind of fungus which the spores developed under cultivation; the spores were pale or olive-coloured and oval, probably from some form of smut. Angus Smith found in water through which the

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[*] Air and Rain. b. 504.

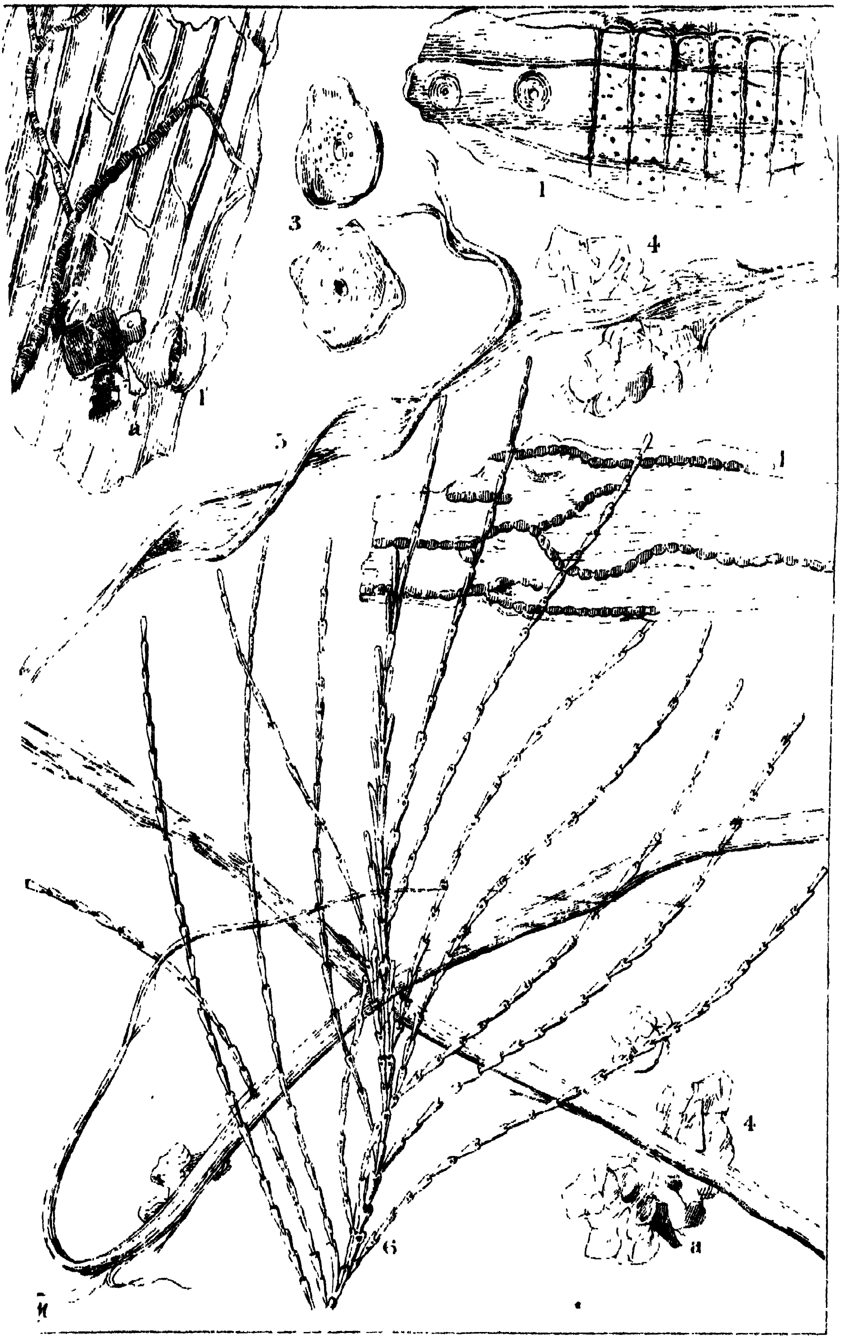
[†] Comptes Rendus de l'Acad., Oct. 1867, b. 637.

[‡] Die Zersetzungsgase als Ursache zur Weiter-verbreitung der Cholera, 1869.

[§] *Op. cit.*

[||] Maddox, Monthly Journal of the Microscopical Society, June 1870, and February 1871.

Plate V.



[illegible]

## DESCRIPTION OF PLATE V.

### *External Air.*

Fig. 1. Fragment of Pine-wood.
1′. Epidermis of Hay, with Fungus attached.
2. Linen fibres. N.B. The thick fibres crossing in lower third of plate.
3. Epithelium (nucleated) from the mouth.
4. Do. detached from the skin.
5. Cotton fibre.
6′. Feather, or Down.
*a.* Charred vegetable particles, and mineral matter.

## DESCRIPTION OF PLATE VI.

### *Accident Ward.*

Fig. 1′. Epidermis of Hay, with Fungus attached.
2. Linen fibre.
2′. Fungus filament. N.B. Long narrow filament in upper left of plate.
3. Nucleated Epithelium from the mouth.
3*a*. Pus cells.
4. Worn Epithelium from the skin.
4*a*. Charred vegetable particles. 4*d*. Fungus spores.
5. Cotton fibre.
6. Woollen fibre.
7. Fragments of Insects.
8. Pine Pollen.
9. Dried-up Palmellaceous Frond.
10. Ciliated spore, probably of *Vaucheria*.

air of Manchester was drawn innumerable spores. Mr Dancer has calculated that in a single drop of the water 250,000 fungoid spores as well as mycelium were present, but as the water was not examined for some time there may have been growth. Mycelium of fungus seems uncommon in the air, but is sometimes found. The cells of the *Protococcus pluvialis* are not uncommon, and perhaps of other algæ. On the whole, the experiments of Maddox show that in his locality (near Southampton), it is incorrect to speak of the air being loaded with fungoid spores; they can be found, but are not very numerous. Blackley ("Experimental Researches on the Causes and Nature of Catarrhus Aestivus," 1873,) says the amount of spores collected on a slide in four hours amounted to 30,000 or 40,000 per square inch. Dr D. D. Cunningham[*] says that in the air in the suburbs of Calcutta, spores are constantly present, and usually in considerable numbers. He gives a large number of beautiful drawings.

(*c*) Parts of flowers, especially pollen,[†] in the spring and summer are very common, cuticular scales, vegetable fibres and hairs, seed capsules, globular cells, &c.[‡] Near habitations are also found bits of wood often withered or burnt, bits of charcoal, starch grains, cotton and wool fibres, &c. All these substances appear from Watson's experiments to be more abundant in land than sea air, as might, indeed, be expected.

(*d*) Animals, or portions, such as scales from the wings of moths and butterflies; portions of the wings of insects; legs of spiders, bits of spiders' webs, and similar objects, are not uncommon; but sometimes even living animals are found of some size, apparently rhizopods and amœbiform bodies.

(*e*) Mineral substances, fine particles of sand, clay, and chalk are generally found, even when there is no dust-storm, and are much more common when the ground is dry; rain, indeed, appears not only to prevent these particles from being lifted, but also to precipitate those in the air.

In manufacturing districts, or near a railway, there may be even large particles of metals, or pottery clay, or stone in the external air; in the dust collected from a railway carriage near Birmingham, Mr Sidebotham[§] found many large particles of iron capable of attraction by a magnet, and being, in fact, fused particles of iron often covered with spikes and excrescences.

In towns with macadamised roads, dust and remains of horse droppings, finely powdered by the traffic, pass into the air, and as this is more common in dry weather, the sanitary importance of watering and washing the streets of great traffic is manifest.

Mr Tichborne has published[||] some analyses of the street dust of Dublin; it contained from 29·7 per cent. of organic matter (at the top of a pillar 134 feet high) to 45·2 per cent. (in the air of a street); the organic matter was chiefly stable manure finely ground; it acted as a ferment, and reduced nitrate of potassium into nitrite; it had, therefore, a strong deoxidising power. The plate (No. V.), drawn by Dr J. D. Macdonald, R.N., F.R.S., shows some of the substances found in the external air in the garden of St Mary's Hospital, Paddington.[¶]

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[*] Ninth Annual Report of the Sanitary Commissioner with the Government of India.

[†] Blackley (*op. cit.*) shows that pollen is in large quantities, sometimes amounting to 7870 grains per square inch of slide. In the upper strata of the air (at 400 to 500 feet) he found much more than in the lower, on an average 19 times as much. Cunningham (*op. cit.*) also found pollen in large quantity.

[‡] See observations on the suspended matters of land and sea air, by Dr Watson, Staff Surgeon, for a description of a good plan of examining the air, and for some drawings. Army Medical Department Report, vol. xi. p. 529 (1871).

[§] Chemical News, October 1871.

[||] Ibid. Oct. 1870.

[¶] From "Three Reports on the Sanitary Condition of St Mary's Hospital, Paddington, by Surgeon-Major F. de Chaumont, M.D., 1875-6."

(*f*) It cannot be doubted that various organic substances dried in the ground and finely pulverised, may be lifted into the air by winds, and may be carried to great distances; under the microscope the particles would probably appear formless, and could not be referred to any special class, but would be included under the term of "dust," or "amorphous matter." In this way it is believed that some diseases may be propagated; cholera, for example, by the particles of dried excreta lifted and carried by the wind, and smallpox and scarlet fever by the disintegrated epidermis or dried discharges. In the case of smallpox and scarlet fever, the distances to which the "contagions" spread by means of the air is certainly inconsiderable.[*]

Some of the various particles of different kinds thus suspended in the air reflect and scatter the rays of light, and produce the appearance of fine motes, which are familiar to every one, as seen in the course of a ray of light passing through a dark room, or when an electric beam is transmitted through a tube. When the air is kept motionless they subside, so that most of them have some weight, though some are so light as not to subside in rarified air (Tichborne); when heated, Tyndall has shown that some of them are burnt, and a little bluish mist arising from the combustion can even be perceived; the destructible nature proves, of course, the organic origin of those consumed, but does not show whether they are organised or not.

### *Suspended Matters in Enclosed Spaces.*

1. *Rooms inhabited by Healthy Persons.*—In all inhabited rooms which are not perfectly ventilated, the presence of scaly epithelium, single and tesselated; round cells like nuclei, portions of fibres (cotton, linen, wool), portions of food, bits of human hair, wood, and coal, can be found in addition to the bodies which are present in the external air, though, as shown by Watson, mineral matters and vegetable matters are not so plentiful, as the comparative stillness of the air allows them to fall.[†]

In some cases articles of furniture may furnish certain substances; the flock wall-papers, coloured green by arsenical preparations (especially Scheele's green and Schweinfürth green), give off little particles of arsenical dust into the room;[‡] and it has been shown by Professor Fleck[§] that the arsenious acid in the Schweinfürth green, when in contact with moist organic substances, and especially starch sizing, forms arseniuretted hydrogen, which diffuses in the room, and is no doubt the cause of some of the cases of arsenical poisoning from green papers.

2. *Sick-Rooms.*—In addition to being vitiated by respiration, the air of sick-rooms is contaminated by the abundant exhalations from the bodies, and by the effluvia from discharged excretions. The quantity of organic matter is known to be large, but it is difficult at present to give a quantitative statement. Moscati, who (in 1818) condensed the watery vapour of a ward at Milan, describes it as being slimy, and as having a marshy smell. The peculiar smell of an hospital is indeed very remarkable, and its similarity in hospitals of different kinds seems to show that the odorous substance has a

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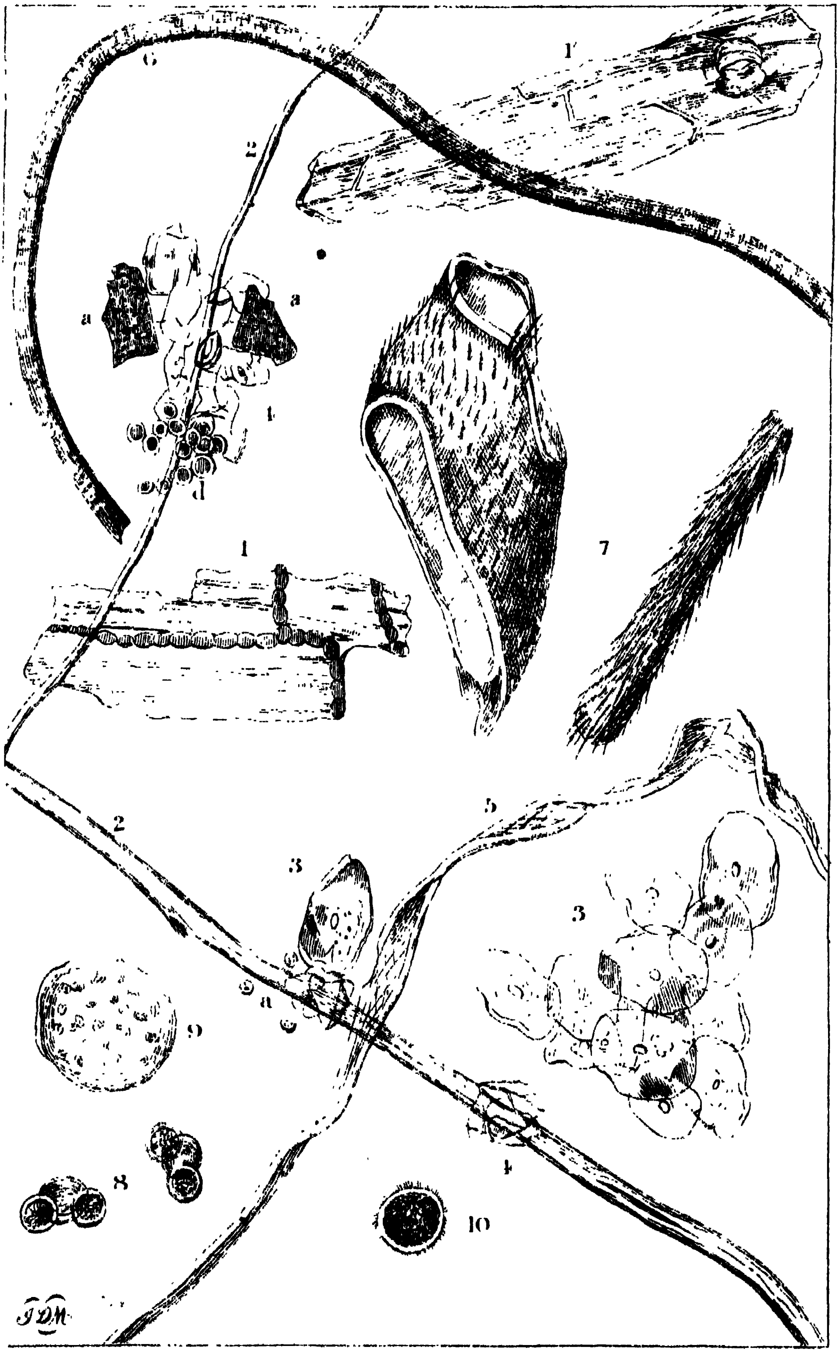
[*] In the air of the back-yard of another London hospital, I found considerable quantities of epithelium; and in the "dirty linen area," where the foul linen was kept in crates till washed, I found not only epithelium, but even pus globules, and also a quantity of fatty crystals, apparently from dressings. There were also Bacteria, both free and in the zooglæal form. (F.de C.)

[†] Numerous observations on the air of barracks and military hospitals have been made by medical officers of the army, especially by Drs de Chaumont, Frank, Hewlett (of Bombay), Stanley, Baynes Reed, Venner, Watson, and many others. (See the Army Medical Department Annual Reports, from 1860–70).

[‡] Halley and many others.

[§] Zeitsch. für Biologie, bd. viii. p. 445 (1872).

Plate VI.



ACCIDENT WARD, St MARY'S HOSPITAL LONDON similar composition in many cases. The reaction of ozone appears not to be given in such an atmosphere.

Devergie found an "immense amount" of organic matter in the air in the vicinity of a patient with hospital gangrene.

The dust of a ward in St Louis, in Paris, examined by Chalvet, was found in one experiment to contain 36 per cent. of organic matter, and in another 46 per cent. When burnt, it gave out an odour of horn. The dust collected in hospitals for diseases of the skin is stated by Gailleton to be full of sporules of the Trichophyton. They can be found in the air of the ward when condensed by ice.

Much interest was excited in 1849 by the discovery by Drs Brittan and Swayne, of Clifton, of bodies very like fungi in the air of a cholera ward; later researches lead to the opinion that this observation was perfectly correct, though the connection between these fungi and cholera is still quite uncertain. In 1849, also, Dr Dundas Thomson drew the air of a cholera ward through sulphuric acid; various suspended substances were arrested, starch, woollen fibres, epithelium, fungi or spores of fungi, and vibriones. Mr Rainy also found in the air of a cholera ward in St Thomas' Hospital, the spores and mycelium of fungi and bacteria. Some of these bodies were found, however, in the open air. In hospitals for skin diseases the Achorion has been detected in the air where there are patients with favus; and Tilbury Fox* has figured the spores (clustered and in chains), and the mycelium of the Trichophyton in a ward with a number of children with tinea circinata.

The scaly and small round epithelia found in most rooms are in large quantity in hospital wards; and probably in cases where there is much expectoration or exposure of pus or puriform fluids to the air, the quantity would be still larger.

Considering that the pleuro-pneumonia of cattle is probably propagated through the pus and epithelium cells of the sputa passing into the air-cells of other cattle; that even in man there is evidence of a pneumonic or phthisical disease being contagious (Bryson, "Cases in the Mediterranean Fleet"), the floating of these cells in the air is worthy of all attention. It may explain some of those curious instances of phthisis being apparently communicated. In the air of a phthisical ward at Netley, Dr Watson not only found pus cells, but bodies which were not found in the external air or in the rooms of healthy persons, and which were very like the cells seen in tuberculous matter. In military granular conjunctivitis (gray granulations), the remarkable effect of ventilation in arresting the spread (Stromeyer) seems to show that we have here a similar case, and that ventilation acts by diluting, oxidising, and drying the cells thrown off from the conjunctivæ. In small-pox wards, Bakewell has found unequivocal evidence of minute scales of small-pox matter in the air. It seems probable that the discovery of suspended matters of this kind will lead to most important results.† The possibility of a direct transference from body to body of cells undergoing special chemical or vital changes is thus placed beyond doubt, and the doctrine of contagion receives an additional elucidation. It remains to be seen whether pus and epithelium cells becoming dried in the atmosphere can again, on exposure to warmth and moisture, undergo the changes which had been interrupted, or whether they would not rather break down into impalpable particles, and then be totally oxidised and destroyed. It is now generally admitted that protophytes like the *Protococcus pluvialis*, may be dried and yet retain their vitality even for years, and may be blown about in atmospheric currents; but it would not be right to infer a similar power on the part of epithelium or pus cells.

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* Lancet, January 1872.

† In the accident ward of St Mary's Hospital, Paddington, I found pus cells in the air, near some beds which had a bad reputation for erysipelas. See plate drawn by Dr Macdonald, (Report on St Mary's *op. cit.*). (F. de C.)

3. *Workshops, Factories, and Mines.*—Grinding of steel and iron, and stones; making metallic and pearl buttons; melting zinc; melting solder; carding and spinning textile fabrics of all kinds; grinding paint; making cement, and in fact almost innumerable trades cause more or less dust derived from the fabrics and materials, to pass into the air.

Dr Sigerson[*] found a black dust composed of carbon, iron (in the shape of small jagged pieces, and also as hollow balls $\frac{1}{2000}$ of an inch in diameter), and ash, in metal shops. In the air of a printing office there was enough antimony to be chemically detected. In the air of stables were equine hairs, epithelium, moth cells, ovules, and various fungi.

In addition to these suspended matters, which vary with the kind of work, the air of workshops is largely contaminated by respiration and by the combustion of gas (see below and page 105).

In mines the suspended matters are made up of the particles of the particular substance which is being worked, or of rock excavated to obtain metals, of sooty matters from lamps and candles, and of substances derived from blasting (see page 112).

## SUB-SECTION II.—GASEOUS SUBSTANCES.

A great number of gases may pass into the atmosphere either from natural causes or from the works of man.

*Compounds of Carbon.*—Carbonic acid (abnormal if exceeding 5 in 10,000 parts), carbonic oxide, carburetted hydrogen, and peculiar substances (gaseous) in sewer air.

*Compounds of Sulphur.*—Sulphurous acid, sulphuric acid, sulphuretted hydrogen, ammonium sulphide, and carbon bisulphide.

*Compounds of Chlorine.*—Hydrochloric acid from alkali works.

*Compounds of Nitrogen.*—Ammonia and ammonium acetate, sulphide, and carbonate (normal in small amount?), and nitrous and nitric acids.

*Compounds of Phosphorus.*—Phosphoretted hydrogen.

*Organic Vapours.*—Of the exact composition of the vapours, often fœtid, which arise from various decomposing animal matters, little is known. The vapours of sewage have been examined by Odling, and were found to be carbo-ammoniacal, containing more carbon than methylamine, and less than ethylamine.

## SUB-SECTION III.—NATURE OF IMPURITIES IN CERTAIN SPECIAL CASES.

### *Air Vitiated by Respiration.*

An adult man, in ordinary work, gives off in twenty-four hours from 12 to 16 cubic feet or more, according to weight, of carbonic acid gas, and also emits an undetermined quantity of carbonic acid gas by the skin. On an average, an adult man, not doing excessive work, may be considered to give to the atmosphere every hour not less than ·6 cubic feet of carbonic acid. Pettenkofer states the amount at about 0·7.[†] Women give off less, and children and old people also give off a smaller amount.

The amount of carbonic acid in pure air being assumed to be on an average

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[*] British Medical Journal, June 1870, from Memoirs of the Irish Academy, in which publication are some excellent observations by the same writer.

[†] This is the quantity adopted by Roth and Lex (Militär-Gesundheitspflege).

0·4 per 1000, or four volumes per 10,000, the quantity in the air of the rooms vitiated by respiration varies within wide limits, and many analyses will be found in books. The following table is a part of the numerous experiments on barrack-rooms by Dr de Chaumont on this point, and is especially valuable, because the amount of carbonic acid in the external air was simultaneously determined. The analyses were made at night, and when the men were in the rooms. The cubic space per head was 600 feet in the barracks and from 1200 to 1600 in the hospitals.

The last column of the table shows the condition of the ventilation as measured by the carbonic acid; it is very satisfactory in the new barracks (Gosport and Chelsea), but is much less so in the old barracks and casemates. The Herbert and Hilsea military hospital show excellent ventilation, while the old-fashioned Portsmouth garrison hospital is very bad in this respect. The prison cells show, in all cases, a very high degree of respiratory impurity, and this must be one of the depressing influences of long cell confinement. Wilson ("Handbook of Hygiene") gives some important information. In cells (in Portsmouth Convict Prison) of 614 cubic feet, always occupied, he found the $CO_2 = 0{\cdot}720$ per 1000; the prisoners were healthy and had a good colour. In cells of 210 cubic feet, occupied only at night by prisoners employed outside during the day, he found 1·044 per 1000 of $CO_2$; the occupants were all pale and anæmic.

The carbonic acid of respiration is equally diffused through the air of a room (Lassaigne, Pettenkofer, Roscoe); it is very rapidly got rid of by opening windows (Gore), and in this respect differs from the organic matter, and probably from the watery vapour; neither appears to diffuse rapidly or equably through a room.

*Amount of Carbonic Andydride in* 1000 *Volumes of Air* (*de Chaumont*).

| | $CO_2$ in External Air. | $CO_2$ in Room | | Mean Respiratory Impurity. |
|---|---|---|---|---|
| | | Largest Amount found. | Mean Amount. | |
| BARRACKS. | | | | |
| Gosport New Barracks, | ·430 | 1·846 | ·645 | ·215 |
| Anglesey Barracks, | ·393 | 1·971 | 1·404 | 1·011 |
| Aldershot, | ·440 | 1·408 | ·976 | ·536 |
| Chelsea, | ·470 | 1·175 | ·718 | ·248 |
| Tower of London, | ·420 | 1·731 | 1·338 | ·898 |
| Fort Elson (Casemate), | ·425 | 1·874 | 1·209 | ·784 |
| Fort Brockhurst (Casemate), | ·422 | 1·027 | ·838 | ·416 |
| MILITARY AND CIVIL HOSPITALS. | | | | |
| Portsmouth Garrison Hospital, | ·306 | 2·057 | ·976 | ·670 |
| Portsmouth Civil Infirmary, | ·322 | 1·309 | ·928 | ·606 |
| Herbert Hospital, | ·424 | ·730 | ·472 | ·048 |
| Hilsea Hospital, | ·405 | ·741 | ·578 | ·173 |
| St Mary's, Paddington, | ·560 | 1·534 | ·847 | ·287 |
| MILITARY AND CIVIL PRISONS. | | | | |
| Aldershot Military Prison—Cells, | ·409 | 3·484 | 1·651 | 1·242 |
| Gosport Military Prison—Cells, | ·555 | 2·344 | 1·335 | ·780 |
| Chatham Convict Prison—Cells, | ·452 | 3·097 | 1·691 | 1·239 |
| Pentonville Prison—Cells—Jebb's system. | ... | 1·926 | ·989 | ... |

The amount of carbonic acid is often much greater than in the above instances. In a boys' school with 67 boys, and 4640 cubic feet (= 69 cubic feet per head), Roscoe found 3·1 parts of $CO_2$ per 1000. In Leicester, in a room with six persons, and only 51 cubic feet of space per head, and with three gas lights burning, Mr Weaver* found the carbonic acid to be 5·28 parts per 1000; while, in a girls' schoolroom (70 girls, and 10,400 cubic feet), or 150 cubic feet per head, Pettenkofer found no less than 7·230 parts per 1000. In many schools, workrooms, and factories, the amount of respiratory impurity must be as great as this, and doubtless a constant unfavourable effect is produced on health. Dr Hayne (in H.M. ship "Doris") found the $CO_2$ to range from 1·03 to 3·21 between decks, the latter quantity being in the ward-room with the scuttles in.† In the Arctic Expedition of 1875–6, Dr Moss found as much as 4·82 in the ward-room of the "Alert," "room feeling very close;" and Dr Ninnis found 5·57 in the lower deck of the "Discovery."

In a horse stable at the Ecole Militaire, the amount was 7 per 1000. At Hilsea, with a cubic space of 655 cubic feet per horse, the amount was 1·053; and in another stable, with 1000 cubic feet per horse, only ·593 per 1000 (de Chaumont). Märcker found 8·5 in a stable in Gottingen, and no less than 17·07 in a byre.

By the skin and lungs pass off from 25 to 40 ounces of water in 24 hours, to maintain which, in a state of vapour, 211 cubic feet of air per hour are necessary on an average. Of course, however, temperature and the hygrometric condition of the air greatly modify this. Organic matter is also given off from the skin and lungs, the amount of which has never been precisely determined. Nor is it possible, at present, to estimate it correctly. This organic matter must be partly suspended, and is made up of small particles of epithelium and fatty matters detached from the skin and mouth, and partly of an organic vapour given off from the lungs and mouth. The organic matter from the lungs, when drawn through sulphuric acid, darkens it; through permanganate of potash, decolorises it; and through pure water, renders it offensive. Collected from the air by condensing the watery vapour on the sides of a globe containing ice (as by Taddei in the wards of the Santa Maria Novella), it is found to be precipitated by nitrate of silver, to decolorise potassium permanganate, to blacken on platinum, and to yield ammonia. It is therefore nitrogenous and oxidisable. It has a very fœtid smell, and this is retained in a room for so long a time, sometimes for four hours, even when there is free ventilation, as to show that it is oxidised slowly. It is probably in combination with water, for the most hygroscopic substances absorb most of it. It is absorbed most by wool, feathers, damp walls, and moist paper, and least by straw and horse-hair. The colour of the substance influences its absorption in the following order:—black most, then blue, yellow, and white. It is probably not a gas, but is molecular, and floats in clouds through the air, as the odour is evidently not always equally diffused through a room. In a room, the air of which is at first perfectly pure, but is vitiated by respiration, the smell of organic matter is generally perceptible when the $CO_2$ reaches ·7 per 1000 volumes, and is very strong when the $CO_2$ amounts to 1 per 1000.‡ From experiments made at Gravesend, Netley, Aldershot, and Hilsea, by various medical officers,§ it has been shown that the amount of potassium permanganate destroyed by air drawn through its solution is generally in proportion to the amount of carbonic acid of respiration.

It is indeed asserted by Gaultier de Claubry ("Ann. d'Hygiene," April 1861,

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* Mr Weaver gives several good analyses in different public and private rooms in Leicester. *Lancet*, July and August 1872.

† Med. Chir. Trans. vol. lvii.

‡ On this point see table at page 142.

§ By Drs de Chaumont, Hewlett (Bombay Army), St John, Stanley, Brynes Reed, Innes, Venning, Martin, and others.

p. 348), that in barracks, some minutes only after the soldiers had entered, the smell of organic matter was perceptible, though there was at that time no augmentation in carbonic acid detected.

When the air of inhabited rooms is drawn through pure water, and the free ammonia got rid off, distillation with alkaline permanganate, in the method of Wanklyn, gives a perceptible quantity of "albuminoid ammonia." In a bed-room at 9 P.M., A. Smith* found ·1901 milligrammes in 1 cubic metre of air; at 7 A.M. there were ·3346 milligrammes in each cubic metre.

Mr Moss (apothecary to the Forces) has made some careful experiments on the air of rooms, and has compared it, in some cases, with the external air (*Lancet*, Nov. 1872). The average of eight observations in the external air (at Portsmouth) gave 0·0935 of free $NH_3$, and 0·0886 of albuminoid $NH_3$ in milligrammes per cubic metre. In the Portsmouth General Hospital he found the free $NH_3$ as high as 0·855, and the albuminoid 1·307.

The following is from Dr de Chaumont's Reports on the Ventilation Experiments at St Mary's Hospital, Paddington.

*Milligrammes per Cubic metre.*

| | Free $NH_3$ | Albuminoid $NH_3$. | Organic oxygen. | Total oxygen for oxidisable matter. | Remarks. |
|---|---|---|---|---|---|
| External air, July 1875, . | 0·3574 | 0·5280 | ... | 1·4300 | Air damp and still, wind S.W. slight. |
| Wards, . | 0·6680 | 0·4710 | ... | 1·4900 | |
| Do. . . | 0·6669 | 0·6770 | ... | 1·5100 | |
| Do. . . | 0·3519 | 0·6915 | ... | 1·3600 | |
| External air, August 1876, . | 0·0163 | 0·5206 | 0·4444 | 0·5714 | Air dry and warm, wind S.E. by E., fresh. |
| Wards, . | 0·0497 | 0·4622 | 0·3747 | 9·5621 | |
| Do. . . | nil. | 0·2824 | 0·2571 | 0·5142 | |
| Do. . . | 0·0310 | 0·3576 | 0·3101 | 0·3567 | |
| Do. . . | 0·0127 | 0·5259 | 0·2225 | 0·4451 | |
| Do. . . | 0·0100 | 0·3684 | 0·4420 | 0·6315 | |

It is evident that the condition of the external air, with regard to movement and humidity, has a great deal to do with the amount of organic matter. The nitrogen acids are also met with; in one instance, in the above experiments, they reached in a ward 28·484 per metre, of which 0·7392 was nitrous, and the rest nitric acid.

### *Air Vitiated by Combustion.*

The products of firing pass out into the atmosphere at large; those of lighting are for the most part allowed to diffuse in the room.

*Coal* of average quality gives off in combustion—

1. Carbon.—About 1 per cent. of the coal is given off as fine carbon and tarry particles.
2. Carbonic acid.—In Manchester, Angus Smith calculated some years ago that 15,000 tons of carbonic acid were daily thrown out.
3. Carbonic oxide.—The amount depends on the perfection of combustion.
4. Sulphur and sulphurous and sulphuric acids.—The amount of sulphur in coal varies from ½ to 6 or 7 per cent. In the air of Manchester, A. Smith found 1 grain of sulphuric acid in 2000 and 1076 cubic feet.

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* Air and Rain, p. 436.—If expressed as grammes per million cubic metres, the amount is 190·114 and 334·601; in grains, in 1 million cubic feet, the numbers are 83·074 and 146·210.

5. Carbon bisulphide.
6. Ammonium sulphide, or carbonate.
7. Sulphuretted hydrogen (sometimes).
8. Water.

From some manufactories there pour out much greater quantities of $SO_2$ (copper works), arsenical fumes, sulphuretted hydrogen, carbonic acid, &c.

For complete combustion, 1 ℔ of coal demands about 240 cubic feet of air.

*Wood* produces carbonic acid and oxide and water in large quantity, but few compounds of sulphur. 1 ℔ of dried wood demands about 120 cubic feet of air for complete combustion.

*Coal-gas*, when fairly purified, is composed of—

| | | | |
|---|---|---|---|
| Hydrogen, | 40 | to | 45·58 |
| Marsh gas (light carburetted hydrogen), | 35 | to | 40 |
| Carbonic oxide, | 3 | to | 6·6 |
| Olefiant gas (ethylene), | 3 | to | 4 |
| Acetylene, | 2 | to | 3 |
| Sulphuretted hydrogen, | 0·29 | to | 1 |
| Nitrogen, | 2 | to | 2·5 |
| Carbonic acid, | 3 | to | 3·75 |
| Sulphurous acid,<br>Ammonia or ammonium sulphide,<br>Carbon bisulphide, | ·5 | to | 1<br>(or in the best cannel-coal gas only traces.) |

In some analyses the carbonic oxide has been as high as 11 per cent., and the light carburetted hydrogen 56; in such cases the amount of hydrogen is small. As much as 60 grains of sulphur have been found in 100 cubic feet of gas.* The Parliamentary maximum is 20 grains in 100 cubic feet. In badly purified gas there may be a great number of substances in small amount, especially hydrocarbons and alcohols, such as propylene, butylene, amylene, benzole, xylol, some of the nitrogenous oily bases, such as pyrrol, picoline, &c.†

When the gas is partly burnt, the hydrogen and light and heavy carburetted hydrogens are almost destroyed; nitrogen (67 per cent.), water (16 per cent.), carbonic acid (7 per cent.), and carbonic oxide (5 to 6 per cent.), with sulphurous acid and ammonia, being the principal resultants. And these products escape usually into the air of rooms. With perfect combustion there will be little carbonic oxide.

According to the quality of the gas, 1 cubic foot of gas will unite with from ·9 to 1·64 cubic feet of oxygen, and produces on an average 2 cubic feet of carbonic acid, and from ·2 to ·5 grains of sulphurous acid. In other words, 1 cubic foot of gas will destroy the entire ogygen of about 8 cubic feet of air. One cubic foot of gas will raise the temperature of 31,290 cubic feet of air 1° Fahr.

*Oil.*—A lamp with a moderately good wick, burns about 154 grains of oil per hour, consumes the oxygen of about 3·2 cubic feet of air, and produces a little more than ½ a cubic foot of carbonic acid; 1 ℔ of oil demands from 140 to 160 cubic feet of air for complete combustion.

A candle of 6 to the ℔ burns per hour about 170 grains.

The products of the combustion of coal and wood pass into the atmosphere at large, and usually are at once largely diluted. Diffusion and the ever-moving air rapidly purify the atmosphere from carbonic acid.

It is not so, however, with the suspended carbon and tarry matters, which are too heavy to drift far, or to ascend high. As a rule, the particles of carbon are not found higher than 600 feet; and the way it accumulates in the lower strata of the atmosphere can be seen by looking at any lofty building in London. The air of London is so loaded with carbon, that even when there is no fog, particles can be collected on Pouchet's aeroscope when only a very small quantity of air is drawn through.

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* Chemical News, March 1865, p. 154.

† For a fuller list of these substances, which do not appear very important, see Pappenheim's Handbuch der San. Pol. band iii. Supp. p. 261.

It is apparently chiefly from combustion, and in some cases from chemical works, that the air of towns contains so much acid as to make rain water acid. In Manchester, in 1868, Angus Smith found the rains to contain from 5·6 grains to 1·4 grain of sulphuric acid (free and combined), and from 1·277 to ·0278 grains of hydrochloric acid per gallon. In Liverpool and Newcastle air the same thing occurs; the sulphuric acid is always larger in amount than the hydrochloric.

Sulphurous and sulphuric acid also appear to be less rapidly removed, as Angus Smith found a perceptible quantity in the air of Manchester; and the rain water is often made acid from this cause.

The products of gas combustion are for the most part allowed to escape into rooms, but certainly this should not be allowed, when gas is burnt in the large quantities commonly used. The immense quantity of gas often used causes great heat, humidity of the air, and there is also some sulphurous acid, an excess of carbonic acid, and, probably, a little carbonic oxide, to which some of the effects may be due. Weaver* found as much as 5·32 volumes of carbonic acid per 1000 in the room of a frame-work knitter in Leicester, with 14 gas lights burning. In other workrooms the amounts were 5·28, 4·6, down to 2·11 volumes per 1000. This amount has a very injurious effect on health, as shown long ago by Dr Guy. In a workshop in Paris, with 400 men and 400 gas-burners, the health of the men was very bad. General Morin introduced good ventilation, and the number of cases of illness was reduced one-third. The appetite of the men, formerly very bad, greatly improved. According to Dr Zock,† coal gas gives off rather more carbonic acid for an equal illuminating power than oil, but less than petroleum. Dr Odling found for equal illuminating power, that candles gave more impurity to the air than gas.‡ Gas gives out, however, more water.

In tobacco smoke are contained particles of nicotine or its salts (Heubel), and probably of picoline bases. There is also much carbonic acid, ammonia, and butyric acid.

Dr Ripley Nichols has investigated the air in smoking cars on American Railways, and found the $CO_2$ to range from 0·98 to 3·35 per 1000, with a mean of 2·278: in ordinary non-smoking cars the $CO_2$ varied from 1·74 to 3·67, with a mean of 2·32, so that there was not much difference as far as $CO_2$ went. As regards ammonia, however, the difference was great, for (taking the external air ratio as 100) he found in the smoking car from 310 to 575, whilst in the ordinary cars it was only 135 to 175. None of the peculiar products of the combustion of tobacco were found. (Reprint from the 6th Annual Report of the Massachusetts Board of Health).

### *Air Vitiated by Effluvia from Sewage Matter and Air of Sewers.*

*Air of Cesspools.*—The air of cesspools, and especially of the cemented pits which are still common in many continental towns, and which receive little beyond the solid and liquid excreta and some of the house water, is generally highly impure. Lévy § refers to an extreme case, in which the oxygen was lessened to 2 per cent., the nitrogen being 94 and the carbonic acid 4. In this case apparently no other gases were present; but in most instances there is a variable amount of sulphuretted hydrogen[*], ammonium sulphide, nitrogen, carbonic acid, and carburetted hydrogen, in addition to fœtid organic matters. These organic matters are in large amount. 62 feet of the air of a cesspool destroyed, in Angus Smith's experiments, as much potassium permanganate as 176,000 cubic feet of pure air, though perhaps some sulphuretted hydrogen may have been also present. Oesterlen[†] states that these gases will pass easily through walls; and M. Hennezel [‡] has lately noticed that in the "fosses d'aisances" in Paris, even in those covered with stone slabs and earth, the wind blowing down the ventilating tube will force the gas through the neighbouring walls, and then perhaps into the house.

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* Lancet, July 1872.

† Zeitsch. für Biol. band ii. p. 117 (1866).

‡ Medical Times and Gazette, Jan. 9, 1869.

§ Traité d'Hygiène, 3d edit. p. 636.

*The Air of Sewers.*—In sewers the products of decomposition are variable, as not only solid and liquid excreta and house water, but the washings and *débris* of the streets, the refuse of trades, &c., pass into the sewers. As a rule, the products of decomposition of the sewer-water appear to be much the same as noted above—viz., fœtid organic matters, carbo-ammoniacal substances condensing with the water of the air on the cold walls, carbonic acid, nitrogen, light carburetted hydrogen, and sulphuretted hydrogen.[§] The proportions of these gases are variable; [||] the most common are carbonic acid and nitrogen; marsh gas is found when oxidation is impeded, and sulphuretted hydrogen and ammonium sulphide, which form in the sewer-water in most cases, are liberated from time to time. The gases, however, are, as a rule, of far less importance than the fœtid organic matters, the exact nature of which it would be most desirable to examine more thoroughly.

The organic vapour is carbo-ammoniacal; the putrid substance in the sewer water appears, from Odling's observations, to be allied to the compound ammonias; it contains more carbon than methylamine ($NH_2(CH_3)$ ), and less than ethylamine ($NH_2(C_2H_5)$ ).

The composition of sewer air will, of course, vary infinitely with the amount of gases disengaged and the degree of ventilation in the sewer. The quantity of oxygen is sometimes in normal amount; it may, however, be diminished in very badly constructed sewers. Parent-Duchâtelet gave an analysis of the air of a choked sewer in Paris, which contained only 13·79 per cent. of oxygen,* and no less than 2·99 per cent. of sulphuretted hydrogen. Excluding this analysis, the greatest impurity in the old Parisian sewers, as determined by Gaultier de Claubry, in 19 analyses† in 1829, was 3·4 per cent. of carbonic acid, and 1·25 per cent. of sulphuretted hydrogen (in different samples of air). The lowest amount of oxygen was 17·4 per cent. Sulphuretted hydrogen was present in 18 out of 19 cases; the mean of the whole 19 cases being ·81 per cent. The mean amount of carbonic acid in 19 cases was 2·3 per cent. In the present London sewers of good construction the air is much less impure. Dr Letheby found only ·532 per cent. of carbonic acid, a good deal of ammonia, and only traces of sulphuretted and carburetted hydrogen. Dr Miller's experiments in 1867‡ gave a mean of only 0·106 per cent. of carbonic acid in 18 analyses, and ·307 per cent. in 6 other instances, the oxygen being 20·71 per cent. No sulphuretted hydrogen was present. Dr Russell examined the air in the sewers of Paddington in August; the most impure air contained 20·7 oxygen, 78·79 nitrogen, and ·51 volumes of carbonic acid per cent.; there was very little ammonia, and no sulphuretted hydrogen.

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[*] Barker, On Malaria and Miasmata, p. 245.

[†] Oesterlen, Hygiene, 1857, p. 445.

[‡] Ann. d'Hygiene, Oct. 1868, p. 178.

[§] Oesterlen, Handb. der Hyg., 2d edition, p. 445.

[||] Dr Letheby's experiments, as given in his official Report, in his article in the Encyclopædia Britannica (Sanitary Science), &c., and in a letter to Dr Adams (given by Dr Adams in his pamphlet, The Sanitary Aspect of the Sewage Question, 1868, p. 34), are the most complete on this subject. Taking the last statement of his views as representing his opinion I gather that sewer-water (containing 128·8 grains of organic matter per gallon), excluded from air, gave out during 9 weeks 1·2 cubic inches of gas per hour, consisting per cent. of 73·833 of marsh gas, 15·899 of carbonic acid, 10·187 of nitrogen, and 0·081 of sulphuretted hydrogen. When atmospheric air is admitted, I infer that Dr Letheby thinks the chief gases are carbonic acid and nitrogen, with but mere traces of sulphuretted hydrogen. That marsh gas in large quantities can be, however, formed, is shown by Letheby's observations on the gases evolved in the London sewers in 1866 where carbolic acid was used; the gas was frequently fired by the candles of the sewer-men, and was found to contain 88·45 per cent. of marsh gas, the formation of which was favoured, Letheby thinks, by the action of the carbolic acid; and this is probable, since Angus Smith (Disinfectants and Disinfection, p. 25) found the gas given off by the putrid sewage at the bottom of the Medlock, the water over which was free from oxygen, to contain almost the same quantity of marsh gas—viz., 88·81 per cent.; the other gases being carbonic acid, 5.84; and nitrogen, 5·35 per cent. The evolution of marsh gas will therefore, in part at any rate, depend on the amount of exposure, and on the absorption of air by the sewer-water. Letheby's experiments shows less sulphuretted hydrogen than might have been anticipated, both from the large amount of sulphides usually present in sewer-water, and the amount of sulphuretted hydrogen proved to exist in the air of many sewers. With regard to the quantity of gases disengaged, I gave, in a former edition of this work, the amount of 1 to 1½ cubic inch of gas disengaged from London sewage per gallon per hour *in the sewers*, as this is my interpretation of Letheby's account of his experiments, as given in the Encyclopædia Britannica (art. Sanitary Science); but Dr Adams, of Glasgow, has pointed out that Dr Letheby's experiments represent the gases disengaged in the laboratory—*i.e.*, at a higher temperature. The amount of gas evolution in the sewers themselves has not been, I believe, actually determined, and will no doubt vary according to the quantity of water, the temperature, rapidity of flow in the sewer, &c.

It is evident that, if we take the carbonic acid and sulphuretted hydrogen as indices, sewer air has no constant composition. It is sometimes almost as pure as the outside air, while at other times it may be highly impure. But these gases are probably the least important ingredients of sewer air; that organic matters are present is evident from the peculiar fœtid smell, and in some cases they are in large amount; 8000 cubic feet of the air of a house into which sewer air had penetrated destroyed more than 20 times as much potassium permanganate as the same quantity of pure air (Angus Smith). Fungi grow rapidly in such air, and meat and milk soon taint when exposed to it. When the sewer air passes through charcoal these substances are absorbed; they may be partly oxidised, as Dr Miller found some nitric acid in the charcoal, but they also collect in the charcoal, and can be recovered (in part at any rate) from it by distillation.§

We must also suppose, for facts leave us no other explanation, that the unknown agencies which produce typhoid fever may also be present and there can be little doubt that cholera ‖ may occasionally spread in the same way. The poison of yellow fever (as appears likely from the epidemic in Madrid) may also exist in sewer air. Whether small-pox, scarlet fever, &c., can own a similar channel of distribution is uncertain; that dysentery and diarrhœa may also be caused by exhalations proceeding from a foul sewer we cannot doubt, but the precise agency is here also unknown.

The experiments of Professor Frankland ¶ show that solid or liquid matter is not likely to be scattered into the air from the sewage itself by any agitation it is likely to undergo, until gas begins to be generated in it. He found that no ordinary agitation (even greater than sewer water is likely to meet with) would scatter particles of lithia solution into the air, but that the bursting of bubbles of carbonic acid gas was sufficient to effect it.

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* Hygiène publ., t. i. p. 209, footnote, and p. 390.

† Parent-Duchâtelet's Hyg. publique, t. i. p. 389.

‡ Abstract in Chemical News, March 1868.

§ Miller, Chemical News, March 1868.

‖ A case in which sewers probably played a part in the dissemination of cholera is given in my Report on the Cholera in Southampton in 1866 to the Medical Officer of the Privy Council.

¶ Proceedings of the Royal Society. 1877.

Hence he argues (with apparent truth) that sewage becomes dangerous in this way only after the setting in of decomposition, so that if we take proper steps to carry away sewage at once the danger becomes reduced to a minimum.

Dr D. D. Cunningham found large quantities of Bacteria in the air of the Calcutta sewers.

### *Air of Churchyards and Vaults.*

The decomposition of bodies gives rise to a very large amount of carbonic acid. It has been calculated that when intramural burial was carried on in London, 2½ millions of cubic feet of $CO_2$ were disengaged annually from the 52,000 bodies then buried. Ammonia and an offensive putrid vapour are also given off. The air of most cemeteries is richer in carbonic acid (·7 to ·9 per 1000, Ramon da Luna), and the organic matter is perceptibly large when tested by potassium permanganate. In vaults, the air contains much carbonic acid, carbonate or sulphide of ammonium, nitrogen, hydrosulphuric acid, and organic matter. Waller Lewis found little $SH_2$ or CH; or cyanogen, or phosphoretted hydrogen. In his experiments the gas always extinguished flame.

Fungi and germs of infusoria abound.

### *Air vitiated by certain Trades.*

Hydrochloric acid gas, from alkali works.

Sulphurous and sulphuric acids, from copper works—bleaching.

Sulphuretted hydrogen, from several chemical works, especially of ammonia.

Carbonic acid, carbonic oxide, and sulphuretted hydrogen, from brick-fields and cement-works.

Carbonic oxide (in addition to above cases), from iron furnaces, gives rise to from 22 to 25 per cent. (Letheby); from copper furnaces, 15 to 19 per cent. (Letheby).

Organic vapours, from glue refiners, bone-burners, slaughter-houses, hackeries.

Zinc fumes (oxide of zinc), from brassfounders.

Arsenical fumes, from copper-smelting.

Bisulphide of carbon, from some india-rubber works.

### *Air of Towns.*

The air of towns may be vitiated by respiration, combustion, effluvia from the soil, sewers, and trades. The movement of the air tends, however, to continually dilute and remove these impurities, and the heavier particles deposit, so that the air even of manufacturing towns is purer than might have been anticipated. The amount of oxygen in atmospheric air in the purest air near the surface of the earth, being taken as from 20·9 to 20·99 volumes per cent., and the carbonic acid being from ·03 to ·045 per cent., with a mean of ·04, it would appear, from Angus Smith's observations,* that in a crowded part of Manchester, exposed to smoke, the amount of oxygen was from 20·868 to 20·179 per cent.; the average of the street air taken from the laboratory front door was, in Manchester, 20·943; of the air taken from a closet, a midden behind the laboratory, 20·70. In the London air, in the open spaces, the oxygen amounted to 20·95; in the crowded eastern districts to 20·857.† In a foggy frost, in Manchester, when the smoke was not moving much, the amount was 20·91. In Glasgow the average was 20·9092. The variations are, therefore, within narrow limits.

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* Air and Rain, p. 24.

† A. Smith, *op. cit.*, p. 30.

The percentage lessening of oxygen in atmospheric air is partly made up by an increase in the carbonic acid; but if a town is well built, the increase in the carbonic acid is trifling; the mean amount of $CO_2$ for London, in Roscoe's experiments, was only ·037 volumes per cent.; in Manchester, in usual weather, A. Smith found the amount ·0403 per cent.; during fogs, ·0679; in the air above the middens, ·0774 per cent. It is stated that there is a difference between close and open spaces in towns; thus, in the open spaces (parks) in London, the mean amount in A. Smith's experiments was ·0301 per cent.; in Newgate Street (in the City), it was ·0413; in Lower Thames Street (City), ·0428 per cent. It is not, however, stated whether the observations were made simultaneously.[*] In Glasgow, the average carbonic acid was ·0502, and in Perth ·04136 per cent.[†] In foreign cities the amount is greater, and surpasses the normal limit in air. In Madrid, Ramon da Luna found ·0517 as a mean average, and in some cases ·08 per cent.; in Munich, the amount is ·05 per cent. These numbers seem, after all, insignificant, but they are not really so, as the aggregate difference, if only ·01 per cent., is considerable. In the air of towns which burn coal there are also, as noted, an excess of acidity (sulphuric and hydrochloric acids), and various suspended matters (see *ante*), which no doubt have injurious effects.[‡]

The air of most towns, in addition to ammonia, also contains a nitrogenous substance which, when condensed in pure water, can be made to yield albuminoid ammonia, by Wanklyn's method. In various places in London, A. Smith[§] found the amount to average ·1509 milligrammes of albuminoid ammonia in 1 cubic metre. The greatest amount was in a field two miles past Clapham Junction (viz, ·27108 milligrammes per cubic metre), and the least was in Westminster Abbey Yard (·08555 milligrammes). At the shore at Innellan (Firth of Clyde), the amount was ·1378 milligrammes, and the mean in the streets of Glasgow was ·3049 milligrammes per cubic metre. In the air of the Underground Railway, in London, the amount was ·3734 milligrammes.[‖] The mean of Mr Moss's experiments in the open air of Portsmouth was rather less, viz., ·0886 milligrammes of albuminoid ammonia per cubic metre. This ammonia may be derived from the living beings in the air, or from dead organic matter; and to bring out the full meaning of such researches, the chemical must be supplemented by a microscopical examination.

These observations prove how important it is to build towns in such a way as to ensure good perflation and movement of air everywhere, and to provide open spaces in all the densely-crowded parts. The great powers of nature, winds, and the fall of rain, will then, for the most part, keep the atmospheric impurities within limits not injurious to health.

### *Air of Marshes.*

The air of typical marshes contains usually an excess of carbonic acid, which amounts, perhaps, to ·6 or ·8 or more per 1000 volumes. Watery vapour is usually in large quantity. Sulphuretted hydrogen is present, if the water of the marsh contains sulphates, which in presence of organic matter, are converted into sulphurets, from which $SH_2$ is derived by the action of vegetable acids. Carburetted hydrogen is also often present, and occasionally free hydrogen and ammonia, and, it is said, phosphoretted hydrogen.*

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[*] In the neighbourhood of St Mary's Hospital, Paddington, I found the mean $CO_2$ to be 0.056 per cent. in damp still weather, July 1875; the same locality in dry, hot weather, with a good deal of movement of air, 0·0416 per cent. (Aug 1876); in the neighbourhood of University College Hospital, damp weather, 0·0736 per cent. in February 1877. (F. de. C.)

[†] A. Smith, Air and Rain, p. 50, *et seq.*

[‡] There are also nitrous and nitric acids, due probably, to the oxidation of organic matters.

[§] Air and Rain, p. 437. I have stated the results in milligrammes per cubic metre, instead of grammes per million cubic metres.

[‖] In the garden of St Mary's Hospital, Paddington, I found 0·5280 and 0·5206 mgms. per M. C. (See page 105). In the back yard of University-College Hospital 0·2060 and 0·3675. (F. de C.)

Organic matter also exists in considerable quantity. Discovered by Vauquelin (1810 and 1811, in the air collected over the Languedoc marshes) by De Lisle, and again by Moscati (1818, in the air of a Lombardy rice-field), and examined more recently by Boussingault (1829, 1839), Gigot (1859), and Becchi (1861), the organic matter seems to have much the same character always. It blackens sulphuric acid when the air is drawn through it; gives a reddish colour to nitrate of silver; has a flocculent appearance, and sometimes a peculiar marshy smell, and, heated with soda-lime, affords evidence of ammonia. The amount in Becchi's experiments was ·00027 grammes in a cubic metre of air (= ·000118 grains in 1 cubic foot). Ozone, led through a solution of this organic matter, did not destroy it. It is said to destroy quinine. Besides this organic matter, various vegetable matters and animals, floating in the air, are arrested when the air of marshes is drawn through water, or sulphuric acid, and *débris* of plants, infusoria, insects, and even, it is said, small crustacea are found; the ascensional force given by the evaporation of water, seems, indeed, to be sufficient to lift comparatively large animals into the air. Dr M. P. Balestra† has described spores and sporangia of a little algoid plant in the air of Rome and its vicinity, and the same plant is found abundantly in the water of the marshes near Rome. Balestra is inclined to attribute marsh fever to this widely diffused "microphyte granule." It has been stated that ozone is deficient in the air over marshes, but the observations of Burdel ("Recherches sur les fièvres paludéennes," 1858) do not confirm this. He often found as much ozone as in other air. In the air collected from the surface of lakes, containing some aquatic plants, especially the Chara, there is a large proportion of oxygen, and this air gives, near the surface, the reaction of ozone (Clemens), while at some feet above the reaction is lost. This is usually ascribed to the oxidation of organic matter, which rises simultaneously from the water.

### *Air in the Holds of Ships.*

The air in the holds of ships is compounded of exhalations from the wood, bilge-water, and cargo. Owing to the comparative immobility of the air, it often becomes extremely foul. The composition is not known, but the smell of sulphuretted hydrogen is very perceptible, and white paint is blackened. In some cases, when the water-tanks are filled by condensed water from the engines, which is not well cooled, the hold may become extremely hot (100° to 120° Fahr.), and decomposition be much increased.

### *Air of Mines.*

In the metalliferous mines the air, acccording to Angus Smith,† is poor in oxygen (20·5 per cent. sometimes), and very rich in carbonic acid (7·85 per 1000 volumes on a mean of many experiments). It also contains organic matter, giving, when burnt, the smell of burnt feathers, in uncertain amount. These impurities arise from respiration, combustion from lights, and from gunpowder blasting. This latter process adds to the air, in addition to carbonic acid, carbonic oxide, hydrogen and sulphuretted hydrogen, various solid particles, consisting of suspended salts, which may amount to as much as 3 grains in each cubic foot of air. These suspended substances are especially sulphate of potash, carbonate of potash, hyposulphite of potash, sulphide of potassium, sulphocyanide of potassium, nitrate of potassium, carbon, sulphur, and sesquicarbonate of ammonia.

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* Toropoff (of St Petersburg), considers malaria poison gaseous; after removing water, oxygen, and carbonic acid, he found marsh air still yielded 84 to 89 per cent of gaseous matter; whilst hill air gave only 81.

† Comptes Rendus, 1870, No. 3, July, p. 235.

‡ Report on Mines, Blue Book, 1864.

## SECTION II.

## DISEASES PRODUCED BY IMPURITIES IN AIR.

### SUB-SECTION I.—SUSPENDED SOLID MATTERS.

1. *Dead Substances.*—The effect which is produced on the respiratory organs by substances inhaled into the lungs has long been known. Ramazzini and several other writers in the last century, and Thackrah about forty years ago in this country, directed special attention to this point, and since that time a great amount of evidence has accumulated,* which shows that the effect of dust of different kinds in the air is a far more potent cause of respiratory diseases than is usually admitted. Affections of the digestive organs are also caused, but in a much slighter degree. The respiratory affections are frequently recurring catarrhs (either dry or with expectoration) and bronchitis, with subsequent emphysema, although this sequence appears from the figures given by Hirt to be not quite so frequent as was supposed, perhaps from the cough not being violent. Acute pneumonia, and especially chronic non-tubercular phthisis, are also produced. The suspended matters in the air which may produce these affections may be mineral, vegetable, or animal; but it would seem that the severity of the effects is chiefly dependent on the amount of dust, and on the physical conditions as to angularity, roughness, or smoothness of the particles, and not on the nature of the substance, except in some special cases. A large number of the unhealthy trades are chiefly so from this cause; this is the case, in fact, with miners of all kinds.† Mr Simon ‡ states that, with one exception, the 300,000 miners in England break down as a class prematurely from bronchitis and pneumonia caused by the atmosphere in which they live. The exception is most important. The colliers of Durham and Northumberland, where the mines are well ventilated, do not appear to suffer from an excess of pulmonary disease, or do so in a slight degree.

In different mines, also, the amount of pulmonary disease is different, apparently according to the amount of ventilation.

The following table by the Registrar-General is printed in the Report of the Commissioners on Mines, Blue-book, 1864:—

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* The whole subject has been lately very carefully investigated by Hirt. Die Krankheiten der Arbeiter, Erste Theil, Die Staubinhalations-Krankheiten, von Dr L. Hirt, 1871.

† Thakrah enumerates the following in his work on the Effect of Arts, Trades, and Professions on Health, 1832. p. 63:—The workmen who were affected injuriously by the dust of their trades 40 years ago even, and the same list will almost do for the present day: Corn-millers, maltsters, teamen, coffee-roasters, snuff-makers, papermakers, flock-dressers, feather-dressers, shoddy-grinders, weavers of coverlets, weavers of harding, dressers of hair, hatters employed in the bowing department, dressers of coloured leather, workers in flax, dressers of hemp, some workers in wood, wire-grinders, masons, colliers, iron miners, lead miners, grinders of metals, file cutters, machine-makers, makers of firearms, button-makers.

‡ Fourth Report of the Medical Officer of the Privy Council, 1862, p. 15, *et seq.* See also Arlidge in B. and F. Med. Chir, Rev. July 1864, for the effects of the pottery trade.

*Average Annual Deaths per* 1000 *from Pulmonary Disease during the Years* 1860–62 *inclusive.*

| Ages. | Metal Miners in Cornwall. | Metal Miners in Yorkshire. | Metal Miners in Wales. | Males, exclusive of Miners, in Yorkshire. |
|---|---|---|---|---|
| Between 15 and 25 years, | 3·77 | 3·40 | 3·02 | 3·97 |
| ,, 25 ,, 35 ,, | 4·15 | 6·40 | 4·19 | 5·15 |
| ,, 35 ,, 45 ,, | 7·89 | 11·76 | 10·62 | 3·52 |
| ,, 45 ,, 55 ,, | 19·75 | 23·18 | 14·71 | 5·21 |
| ,, 55 ,, 65 ,, | 43·29 | 41·47 | 35·31 | 7·22 |
| ,, 65 ,, 75 ,, | 45·04 | 53·69 | 48·31 | 17·44 |

The enormous increase of lung diseases among the miners after the age of 35, is seen at a glance.

In the pottery trade all classes of workmen are exposed to dust, especially, however, the flat-pressers. So common is emphysema that it is called "the potters' asthma."

So also among the china scourers; the light flint dust disengaged in great quantities is a "terrible irritant." Dr Greenhow states that *all* sooner or later become "asthmatical."

The grinders of steel, especially of the finer tools, are perhaps the most fatally attacked of all, though of late years the evil has been somewhat lessened by the introduction of wet-grinding in some cases, by the use of ventilated wheel-boxes, and by covering the work with linen covers when practicable. The wearing of masks and coverings for the mouth appears to be inconvenient, otherwise there is no doubt that a great amount of the dust might be stopped by very simple contrivances.*

Button-makers, especially the makers of pearl buttons, also suffer from chronic bronchitis, which is often attended with hæmoptysis. So also pin-pointers, some electro-plate workmen, and many other trades of the like kind, are more or less similarly affected.

In some of the textile manufactures much harm is done in the same way. In the carding rooms of cotton, and wool, and silk spinners, there is a great amount of dust and flue, and the daily grinding of the engines disengages also fine particles of steel. Since the cotton famine, a size composed in part of china clay (35·35 grains of clay, in 100 of sizing on an average), has been much used in cotton mills, and the dust arising seems certainly to be producing injurious effects on the lungs of the weaver.†

In flax factories a very irritating dust is produced in the process of hackling, carding, line-preparing, and tow-spinning. Of 107 operatives, whose cases were taken indiscriminately by Dr Greenhow, no less than 79 were suffering from bronchial irritation, and in 19 of these there had been hæmoptysis. Among 27 hacklers, 23 were diseased.‡ In shoddy factories, also, the same thing occurs. These evils appear to be entirely and easily preventable. In some kinds of glass-making, also, the workmen suffer from floating particles of sand and felspar, and sometimes potash or soda-salts.

The makers of grinding-stones suffer in the same way; and children working in the making of sand-paper are seriously affected, sometimes in a very short time, by the inhalation of fine particles of sand into the lungs.

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* See for further particulars and much interesting information Dr Hall's paper read at the Social Science Congress in 1865.

† G. Buchanan's Report on certain Sizing Processes used in the Cotton Manufacture at Todmorden. Ordered to be printed by the House of Commons. May 1872.

‡ Mr Simon's Fourth Report, p. 19.

In making Portland cement, the burnt masses of cement are ground down, and then the powder is shovelled into sacks; the workmen doing this cough a great deal, and often expectorate little masses of cement. I have been informed by some of them that if they had to do the same work every day, it would be impossible to continue it on account of the lung affection.

The makers of matches, who are exposed to the fumes of phosphorus, suffer from necrosis of the jaw, if there happens to be any exposed part on which the fumes can act.

In making bichromate of potash, the heat and vapour employed carry up fine particles, which lodge in the nose and cause great irritation, and finally ulceration, and destruction of both mucous membrane and bone. Those who take snuff escape this. The mouth is not affected, as the fluids dissolve and get rid of the salt. The skin is also irritated if the salt is rubbed on it, and fistulous sores are apt to be produced. No effect is noticed to be produced on the lungs.* Washing the skin with subacetate of lead is the best treatment.

In the process of sulphuring vines the eyes often suffer, and sometimes (especially when lime is used with the sulphur) decided bronchitis is produced.

In some trades, or under special circumstances, the fumes of metals, or particles of metallic compounds, pass into the air. Brassfounders suffer from bronchitis and asthma, as in other trades in which dust is inhaled; but in addition, they also suffer from the disease described by Thackrah as "brass ague," and by Dr Greenhow as "brassfounders' ague." It appears to be produced by the inhalation of fumes of oxide of zinc; † the symptoms are tightness and oppression of the chest, with indefinite nervous sensations, followed by shivering, an indistinct hot stage, and profuse sweating. These attacks are not periodical.

Coppersmiths are affected somewhat in the same way, by the fumes arising from the partly volatilised metal, or from the spelter (solder).

Tinplate workers also suffer occasionally from the fumes of the soldering.

Plumbers inhale the volatilised oxide of lead which rises during the process of casting. Nausea and tightness of the chest are the first symptoms, and then colic and palsy.

Manufacturers of white lead inhale the dust chiefly from the white beds and the packing.

House painters also inhale the dust of white lead to a certain extent, though in these, as in former cases, much lead is swallowed from want of cleanliness of the hands in taking food.

Workers in tobacco factories also suffer in some cases, and there are persons who can never get accustomed to the work; yet with proper care and ventilation it appears‡ that no bad effects ordinarily result.

Workers in mercury, silverers of mirrors, and water gilders (men who coat silver with an amalgam of mercury and gold), are subject to mercurialismus.

Workmen who use arsenical compounds, either in the making of wall papers or of artificial flowers, &c., suffer from slight symptoms of arsenical poisoning, and many persons who have inhaled the dust of rooms papered with arsenical papers have suffered from both local and constitutional effects,—the local being smarting of the gums, eyes, nose, œdema of the eyelids, and little ulcers on the exposed parts of the body; the constitutional being weakness, fainting, asthma, anorexia, thirst, diarrhœa, and sometimes even severe nervous symptoms. Arsenic has been detected in the urine of such persons.

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* Chevallier, Ann. d'Hygiène, July 1863, p. 83.

† Some doubt has been expressed as to those symptoms being produced by *pure* zinc fumes; see Hirt (*op. cit.*) who says that men employed in making zinc houses, where they inhale *pure* zinc fumes without copper, never suffer from brassfounder's ague. On the other hand he describes very graphically the effect of the metallic fumes (copper ?) on himself. The workmen think that drinking large quantities of milk lessens the severity of the attacks.

‡ Hirt, *op. cit.* p. 162–163.

A. Manouvriez* gives an account of the diseases among workmen in France employed in making patent fuel, a mixture of coal-dust and pitch. He says that they suffer from melanodermy, cutaneous eruptions, and epithelial cancers, affections of the eyes, ears, and nose; bronchitis with pulmonary pseudo-melanosis; and gastro-entero-hepatic disorders. Hirt also mentions some of the diseases produced among workmen by the various tar-products.

2. *Living Substances, as Infusoria, Fungi, Algæ, or their germs, or Pollen or Effluvia of Flowers.*—That summer catarrh or hay-fever is produced in many persons by the pollen from grasses (especially *Anthoxanthum odoratum*), trees or flowers, is now generally admitted. The researches of Dr Blackley,† of Manchester (himself a sufferer), have placed the matter beyond a doubt. In his case, at least, it was pollen that produced the disease, and not the effluvia merely. Coumarin had no effect. Grass-pollen (which constitutes 95 per cent. of the pollen floating in the atmosphere) and the pollen from pine-trees were the most powerful in effect. Curiously enough the pollen of poisonous plants, such as the Solaneaceæ, was often comparatively innocuous. It is also known that the spores of certain fungi in falling on a proper soil may cause disease of the skin in men, and that tinea and favus are thus sometimes spread seems certain. The attempt, however, to connect the spread of the specific diseases with fungi or algæ has not yet been successful, in spite of the careful researches of several authors.‡ Dr Salisbury of Ohio has attemped to trace ague to a Palmella; others have ascribed it to the Oscillarineæ generally; and Dr Balestra believes that a special alga is the efficient cause.

Dr Salisbury has also affirmed that the prevalence of measles in the Federal army arose from fungi from mouldy straw. He inoculated himself, his wife, and forty other persons with the fungi, and produced a disease like measles in from 24 to 96 hours. It is stated also that this disease was protective against measles. Dr Woodward (United States Army) has repeated Dr Salisbury's experiments, and does not confirm them.§

Professor Hallier of Jena has to some extent adopted the view that fungi give rise to some of the specific diseases, and that the spores float in the air, and are thus communicated, but the proofs are not satisfactory.||

Dr D. D. Cunningham says that he was unable to connect any disease, in Calcutta, with the occurrence of bacteria or other bodies in the air, either as regards variation in kind or in quantity.

Blackley found that *Chaetonium elatum* (bristle mould) produced nausea, fainting, and giddiness, and the spores of penicillium (inhaled) brought on hoarseness, going on to complete aphonia; the condition lasted two days, and ended in a sharpish attack of catarrh.

3. *The Contagia.*—Under this head it will be convenient to include the unknown causes of the specific diseases. That these in some cases (scarlet fever, small-pox, measles, typhus, enteric fever, plague, pertussis, yellow fever, influenza, &c.,) reach the person through the medium of air (as well as in some cases through water or food) cannot be doubted. Some of these contagia

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* Annales d'Hygiène, March, 1876.

† *Op.cit.*

‡ I refer especially to Adam Neale, Cowdell, Mitchell, Holland, and others.

§ Camp Diseases in the U.S. Army, p. 278. The fungus is a Penicillium. Dr Wood (Professor of Botany in the University of Philadelphia) has advanced (Amer. Jour. of Med. Sci. 1868) some extremely strong botanical arguments against the view that malarial diseases can be owing to Palmella.

|| Many papers on this subject by Hallier and others are contained in Hallier's Zeitschrift für Parasitenkunde.

have in some way a power of growth and multiplication in the body of a susceptible animal, but whether they can find nourishment, and thus grow in the air, is yet doubtful. It seems clear, however, that they can retain the powers of growth for some time, as the smallpox and scarlet fever poisons may infect the air of a room for weeks, and cattle plague and enteric fever poisons will last for months,* and in this they resemble the Protococci and other low powers of life, which can be dried for years, and yet retain vitality.

The exact condition of the agency is unknown; whether it is in the form of impalpable particles, or moist or dried epithelium and pus cells, is a point for future inquiry; and whether it is always contained in the substances discharged or thrown off from the body (as is certainly the case in smallpox), or is produced by putrefactive changes in those discharges, as is supposed to be the case in cholera and dysentery, is also a matter of doubt. Bakewell† has collected dust deposited at a height of 7 or 8 feet in smallpox wards, which contained the minute scabs with the epidermic scales and variolous corpuscles which are thrown off from the skin in smallpox. The modern expositors of the old doctrine of fomites would consider these organic matters to be inconceivably minute particles of living, or to use Dr Beale's phrase, bioplastic matter, which is capable, he believes, of wonderfully rapid growth under proper conditions.‡ From the way in which, in many cases, organic substances in the air are absorbed by hygroscopic bodies, it would appear that it is often combined with, or is at any rate condensed with, the water of the atmosphere.

The specific poisons manifestly differ in the ease with which they are oxidised and destroyed. The poison of typhus exanthematicus is very readily got rid of by free ventilation, by means of which it must be at once diluted and oxidised, so that a few feet give, under such circumstances, sufficient protection. This is the case also with the poison of oriental plague, while, on the other hand, the poisons of smallpox and scarlet fever will spread in spite of very free ventilation, and retain their power of causing the same disease for a long time. Is it that in one case the poison is a mere cloud of molecules; that in the other it is contained in epithelium and pus cells, thrown off from the skin in both cases, and from the throat also in one; and which adhering to walls, clothes, &c., partially dry, can be rendered again active by warmth and moisture? In the case of malaria, the process of oxidation must be slow, since the poison can certainly be carried for many hundred yards; even sometimes for more than a mile in an upward direction (up a ravine for instance), or horizontally, if it does not pass over the surface of water. The poison of cholera also, it is supposed, can be blown by the winds for some distance; but the most recent observations on its mode of spread lead to the conclusion that the portability of the poison in this way has been greatly overrated.

But the specific poisons are not the only suspended substances which thus float through the atmosphere.

There can be no doubt that while purulent and granular ophthalmia most frequently spread by direct transference of the pus or epithelium cells, by means of towels, &c., and that erysipelas and hospital gangrene, in surgical wards, are often carried in a similar way, by dirty sponges and dressings, another mode of transference is by the passage into the atmosphere of disintegrating pus cells and putrifying organic particles, and hence the great effect of free ventilation in military ophthalmia (Stromeyer), and in erysipelas* and hospital gangrene. In both these diseases, great evaporation from the walls or floor seems in some way to aid the diffusion, either by giving a great degree of humidity, or in some other way. The practice of frequently washing the floors of hospitals is well known to increase the chance of erysipelas.

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* The long retention of power by the enteric fever poison is shown by a case related to me by Dr Becher (Army Med. Department Report, vol. 10. p. 237). The typhoid poison appears to have adhered to the walls and ceiling, and to have retained its power to excite disease in another person for a month; it was not destroyed by the heat of a very hot Indian station (Gwalior,) in February.

† Med. Times and Gazette, Dec. 7, 1872.

‡ See chapter on Disinfection for a fuller notice of these points.

It is a question even whether we shall not be obliged to extend this view, and to believe that every pus or epithelium cell, or even formless organic substance, floating in the air, may, if it find a proper place or nidus in or on which it can be received, communicate to its own action, and thus act as a true contagium.

## SUB-SECTION II.—GASEOUS MATTERS.

(*a*) *Carbonic Acid.*—The normal quantity of carbonic acid being ·4 volumes per 1000, it produces fatal results when the amount reaches from 50 to 100 per 1000 volumes; and at an amount much below this, 15 to 20 per 1000, it produces, in some persons at any rate, severe headache. Other persons can inhale, for a brief period, considerable quantities of carbonic acid without injury;† and animals can be kept for a long time in an atmosphere highly charged with it, provided the amount of oxygen be also increased. In the air of respiration, headache and vertigo are produced when the amount of carbonic acid is not more than 1·5 to 3 volumes per 1000; but then organic matters, and possibly other gases, are present in the air, and the amount of oxygen is also lessened. Well-sinkers, when not actually disabled from continuing their work by carbonic acid, are often affected by headache, sickness, and loss of appetite; but the amount of carbonic acid has never been determined.

The effect of constantly breathing an atmosphere containing an excess of carbonic acid (up to 1 or 1·5 per 1000 volumes) is not yet perfectly known. Dr Angus Smith‡ has attempted to determine the effect of carbonic acid *per se*, the influence of the organic matter of respiration being eliminated. He found that 30 volumes per 1000 caused great feebleness of the circulation, with usual slowness of the heart's action; the respirations were, on the contrary, quickened, but were sometimes gasping. These effects lessened when the amount of carbonic acid was smaller, but were perceptible when the amount was as low as 1 volume per 1000—an amount often exceeded in dwelling-houses. At the same time, this is not the case always, for in the air of a soda-water manufactory, where the carbonic acid was 2 per 1000, Smith found no discomfort to be produced. The effects noticed by Smith have not been observed in experiments on animals (by Demarquay, W. Müller, and Eulenberg),§ nor in other cases in men, as in the bath at Oeynhausen, where no effect is produced by the air of the room in which the bathers remain for 30 to 60 minutes, although it contains a large percentage of carbonic acid. It has been supposed that lung diseases, especially phthisis, are produced by carbonic acid; but as this opinion has been drawn merely from the effects of the air of respiration, which is otherwise vitiated, it cannot be considered to stand on any sure basis. Hirt finds no symptoms of chronic poisoning by $CO_2$, even in trades where acute poisoning occasionally occurs.‖

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* See my Reports on St Mary's Hospital, *loc. cit.* (F. de C.)

† It is stated that Sir R. Christison has employed air containing 20 per cent. of carbonic acid as an anæsthetic. (Taylor's Jurisprudence, 1865, p. 713.)

‡ Air and Rain, p. 209, *et. seq.*

§ Quoted by Roth and Lex., *op. cit.* p. 176.

‖ Die Krankheiten der Arbeiter, Erste Abtheilung, 2ter Theil, 1873.

The presence of a large amount of carbonic acid in the air may lessen the elimination of carbonic acid from the lungs, and thus retain the gas in the blood, and in time possibly produce serious alterations in nutrition.

(*b*) *Carbonic Oxide.*—Of the immense effect of carbonic oxide, there is no doubt. Less than one-half per cent. has produced poisonous symptoms, and more than one per cent. is rapidly fatal to animals. It appears from Bernard's, and from Lothär Meyer's observations,[*] that the carbonic oxide, volume for volume, completely replaces the oxygen in the blood, and cannot be again displaced by oxygen, so that the person dies asphyxiated; but Pokrowsky has shown[†] that the carbonic oxide may gradually be converted into carbonic acid, and be in that way got rid of. It seems, in fact, as Hoppe-Seyler conjectured, to completely paralyse, so to speak, the red particles, so that they cannot any longer be the carriers of oxygen. The observations of Dr Kleber[‡] show that, in addition to loss of consciousness and destruction of reflex action, the carbonic oxide causes complete atony of the vessels, diminution of the vascular pressure, and slowness of circulation, and finally, paralysis of the heart. A very rapid parenchymatous degeneration takes place in the heart and muscles generally, and in the liver, spleen, and kidneys. Hirt[§] says that at high temperatures (25° - 32° cent. = 77° - 90° Fahr.) carbonic oxide produces convulsions, but not at low temperatures (8° - 12° cent. = 46° - 53° Fahr.).

(*c*) *Sulphuretted Hydrogen.*—The evidence with regard to sulphuretted hydrogen is contradictory. While dogs and horses are affected by comparatively small quantities (1·25 and 4 volumes per 1000 volumes of air), and suffer from purging and rapid prostration, men can breathe a larger quantity. Parent-Duchâtelet inhaled an atmosphere containing 29 volumes per 1000 for some short time.[||]

When inhaled in smaller quantities, and more continuously, it has appeared in some cases harmless, in others hurtful. Thackrah, in his inquiries, could trace no bad effect. It is said that in the Bonnington chemical-works, where the ammoniacal liquor from the Edinburgh gas-works is converted into sulphate and chloride of ammonium, the workmen are exposed to the fumes of hydrosulphate of ammonia, and of hydrosulphuric acid, to such an extent that coins are blackened; yet no special malady is known to result. The same observations have been made at the Britannia metal-works, where a superficial deposit of sulphuret is decomposed with acids.

Hirt[¶] has no doubt of the occurrence of chronic poison among men who work among large quantities of the gas. The symptoms are chiefly weakness, depression, perfect anorexia, slow pulse, furred tongue, mucous membrane of the mouth pale, as is also the face. Sometimes there is furunculoid eruption in different parts of the body. In some cases there are vertigo, headache, nausea, diarrhœa, emaciation, and head symptoms, "like a case of very slow-running typhus." He notices differences of susceptibility, which is also sometimes increased with custom.

So large a quantity of $SH_2$ is given out from some of the salt marshes at Singapore, that slips of paper moistened in acetate of lead are blackened in the open air, yet, not only is no bad effect found to ensue, but Dr Little has even conjectured (on very disputable grounds, however,) that the $SH_2$ may neutralise the marsh miasma.

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[*] De Sanguine Oxydo Carbonico Infecto, 1858. Reviewed in Virchow's Archiv, band xv. p. 309. See also Letheby, Chemical News, April 1862.

[†] Virchow's Archiv, band xxx. p. 525 (1864).

[‡] Ibid. band xxxii. p. 450 (1865).

[§] *Op. cit.*

[||] On dogs, Herbert Barker found a larger quantity necessary than that stated above: viz. 4·29 per 1000 is rapidly fatal; 2·06 per 1000 may be fatal; but ·5 per 1000 may produce serious symptoms.

[¶] *Op. cit.*

On the other hand, some of the worst marshes in Italy are these in which $SH_2$ exists in large quantity in the air, and, in direct opposition to Little, it has been supposed that the highly poisonous action of the marsh gas is partly owing to the sulphuretted hydrogen. Again, in the making of the Thames Tunnel, the men were exposed to $SH_2$, which was formed from the decomposition of iron pyrites; after a time they became feeble, lost their appetites, and finally passed into a state of great prostration and anæmia. Nor, as far as is known, was there anything to account for this except the presence of sulphuretted hydrogen.*

Dr Josephson and Rawitz† have also investigated in mines effects produced apparently by sulphuretted hydrogen; two forms of disease are produced—pure narcotic, and convulsive and tetanic symptoms. In the first case, the men became pale, the extremities got cold. There was headache, vertigo, a small weak pulse, sweating, and great loss of strength. On this, spasms and tremblings sometimes followed, and even tetanus. These symptoms were acute, and not, as in the Thames Tunnel case chronic. When these attacks occurred, the temperature was high and the air stagnant.

The obversations of Clemens, also, on the development of boils from the passage of $SH_2$ into the drinking water from the air, if not convincing, cannot be overlooked. (See page 55.‡)

The symptoms produced by ammonium sulphide in dogs are said, by Herbert Barker,§ to differ from those of $SH_2$. There is vomiting without purging, quickened pulse, and heat of skin, followed by coldness and rapid sinking. When sulphuretted hydrogen and ammonium sulphide, dissolved in water, are injected into the blood,‖ they, and especially $SH_2$, produce the same symptoms as the injection of non-corpuscular putrid fluids, viz., profuse diarrhœal evacuations, with sometimes marked choleraic symptoms and decided lowering of the temperature of the body, congestions of the lungs, liver, spleen, and kidneys, irritation of the spine, and opisthotonos. But, in this case, a much larger quantity will be introduced than by inhalation through the lungs.

(*d*) *Carburetted Hydrogen.*—A large quantity of carburetted hydrogen can be breathed for a short time; as much, perhaps, as 200 to 300 volumes per 1000. Above this amount it produces symptoms of poisoning, headache, vomiting, convulsions, stertor, dilated pupil, &c.

Breathed in small quantities, as it constantly is by some miners, it has not been shown to produce any bad effects; but there, as in so many other cases, it is to be wished that a more careful examination of the point were made. Without producing any marked disease, it may yet act injuriously on the health. Hirt says that cases of chronic poisoning are not uncommon.

(*e*) *Ammoniacal Vapours.*—An irritating effect on the conjunctiva seems to be the most marked effect of the presence of these vapours. I am not aware of any evidence showing any other effect on the health. (See Schloesing, *Comptes Rendus*, 1875, vols. I. and II.)

(*f*) *Sulphurous Acid Gas.*—The bleachers in cotton and worsted manufactories, and storers of woollen articles, are exposed to this gas, the amount of which in the atmosphere is, however, unknown. The men suffer from bronchitis, and are frequently sallow and anæmic.*

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* Taylors's Med. Jurisp. 1865, p. 727.

† Schmidt's Jahr. band cx. p. 334, and band cxvii. p. 85.

‡ I notice, in the account of the new Laboratory at Leipzig, that Kolbe has made a special arrangement for the supply of $SH_2$ from gasometers, as the custom of each man making the gas himself evolves so much that the health of all who are working in the room suffers. (Das Neue Chem. Lab. von Univ. Leipzig, p. 20.)

§ On Malaria and Miasmata, p. 212.

‖ Weber, Syd. Soc. Year-Book for 1874, p. 227.

When sulphurous acid is evolved in the open air, and therefore at once largely diluted, as in copper smelting, it does not appear to produce any bad effects in men, though from being washed down with rain, it affects herbage, and, through the herbage, cattle, causing affections of the bones, falling off of the hair, and emaciation.

(*g*) *Hydrochloric Acid Vapours* in large quantities are very irritating to the lungs; when poured out into the air, as was formerly the case in the alkali manufactures, they are so diluted as apparently to produce no effect on men, but they completely destroy vegetation. In some processes for making steel, hydrochloric, sulphurous and nitrous acids, and chlorine are all given out, and cause bronchitis, pneumonia, and destruction of lung tissue, as well as eye diseases.†

(*h*) *Carbon Bisulphide.*—In certain processes in the manufacture of vulcanised india-rubber a noxious gas is given off, supposed to be the vapour of carbon bisulphide. It produces headache, giddiness, pains in the limbs, formication, sleeplessness, nervous depression, and complete loss of appetite. Sometimes there is deafness, dyspnœa, cough, febrile attacks, and sometimes even amaurosis and paraplegia (Delpech). The effects seem due to a direct anæsthetic effect on the nervous tissue.

### SUB-SECTION III.—EFFECT OF AIR IMPURE FROM SEVERAL SUBSTANCES ALWAYS CO-EXISTING.

The examination of the effects of individual gases, however important, can never teach us the results which may be produced by breathing air rendered foul by a mixture of impurities. The composite effect may possibly be very different from what would have been anticipated from a knowledge of the action of the isolated substances.

(*a*) *Air rendered Impure by Respiration* (see page 102). The effect of the fœtid air containing organic matter, excess of water and carbonic acid, produced by respiration, is very marked upon many people; heaviness, headache, inertness, and in some cases nausea, are produced. From experiments on animals in which the carbonic acid and watery vapour were removed, and organic matter alone left, Gavarret and Hammond have found that the organic matter is highly poisonous. Hammond found that a mouse died in forty-five minutes, and I have known cases in which the inhalation of such an atmosphere for three or four hours produced in men decided febrile symptoms (increased temperature, quickened pulse, furred tongue, loss of appetite, and thirst), for even twenty-four or forty-eight hours subsequently.

When the air is rendered still more impure than this, it is rapidly fatal, as in the cases of the Black Hole at Calcutta; of the prison in which 300 Austrian prisoners were put after the battle of Austerlitz (when 260 died very rapidly); and of the steamer Londonderry. The poisonous agencies are probably the organic matter and the deficient oxygen, as the symptoms are not those of pure asphyxia. If the persons survive, a febrile condition is left behind, which lasts three or four days, or there are other evidences of affected nutrition, such as boils, &c.

When air more moderately vitiated by respiration is breathed for a longer period, and more continuously, its effects become complicated with those of other conditions. Usually a person who is compelled to breathe such an atmosphere is at the same time sedentary, and, perhaps, remains in a constrained position for several hours, or possibly is also under-fed or intemperate. But allowing the fullest effect to all other agencies, there is no doubt that the breathing the vitiated atmosphere of respiration has a most injurious effect on the health.[*] Persons soon become pale, and partially lose their appetite, and after a time decline in muscular strength and spirits.[†] The aëration and nutrition of the blood seem to be interfered with, and the general tone of the system falls below par. Of special diseases it appears pretty clear that pulmonary affections are more common.

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* On the other hand, persons living in volcanic countries have sometimes a notion that the fumes of sulphurous acid are good for the health; I have been told so by people in the neighbourhood of Vesuvius. (F. de C.)

† Jordan—Canstatt's Jahresb. for 1863, band vii. p. 76.

Such persons do certainly appear to furnish a most undue percentage of phthisical cases; that is, of destructive lung-tissue disease of some kind. The production of phthisis from impure air (aided most potently, as it often is, by coincident conditions of want of exercise, want of good food, and excessive work) is no new doctrine.[‡] Baudelocque long ago asserted that impure air is the great cause of scrofula (phthisis), and that hereditary predisposition, syphilis, uncleanness, want of clothing, bad food, cold and humid air, are by themselves non-effective. Carmichael, in his work on scrofula (1810), gives some most striking instances, where impure air, bad diet, and deficient exercise concurred together to produce a most formidable mortality from phthisis. In one instance, in the Dublin House of Industry, where scrofula was formerly so common as to be thought contagious, there were in one ward 60 feet long and 18 feet broad (height not given), 38 beds, each containing four children; the atmosphere was so bad that in the morning the air of the ward was unendurable. In some of the schools examined by Carmichael, the diet was excellent, and the only causes for the excessive phthisis were the foul air and want of exercise. This was the case also in the house and school examined by Neil Arnott in 1832. Lepelletier (Traité Complet de la Maladie Scrophuleuse) also records some good evidence. Professor Alison, of Edinburgh, and Sir James Clark, in his invaluable work, lay great stress on it. Neil Arnot, Toynbee, Guy, and others, brought forward some striking examples before the Health of Towns Commission (First Report, 1844, vol. i. pp. 52, 60, 69, 79, &c.). Dr Henry MacCormac has insisted with great cogency on this mode of origin of phthisis; and Dr Greenhow, in his "Report on the Health of the People of England," also enumerates this cause as occupying a prominent place.[§]

In prisons, the great mortality which formerly occurred from phthisis, as for example at Millbank (Baly), seemed to be owing to bad air, conjoined with inferior diet and moral depression.

Two Austrian prisons, in which the diet and mode of life were, it is believed, essentially the same, offer the following contrast:—

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[*] See, among a number of other instances, Guy's evidence before the Health of Towns Commission, vol. i. p. 89, *et seq.*, and S. Smith, ibid. p. 37, *et seq.*

[†] See Wilson's Observations on Prisoners, already cited, page 103.

[‡] The following statistics (Ransom, Sanitary Record, vol. vi.) are instructive: Death-rate from diseases of the respiratory organs for all England, 3·54 (1865–76), for Salford 5·12; for registration district of Manchester, 6·10; for township of Manchester in 1874, 7·7; for Westmoreland (one of the healthiest counties) 2·27; for North Wales, 2·51. For diagrams showing the effects of aggregation of population on the ratio of respiratory diseases, see my Lectures on State Medicine, table v. p. 48 (F. de C.)

[§] The observations of the development of what are apparently tubercular lesions from the circulation in the blood of pus or septic matter derived from inoculation in guinea pigs, by Burdon-Sanderson and Wilson Fox, seem to give support to the conjecture, that in these cases of tubercle from foul air, some corpuscular substances may be drawn into, and set up disease of, the lungs.

In the prison of Leopoldstadt, at Vienna, which was very badly ventilated, there died in the years 1834–1847, 378 prisoners out of 4280, or 86 per 1000, and of these no less than 220, or 51·4 per 1000, died from phthisis; there were no less than 42 cases of acute miliary tuberculosis.

In the well-ventilated House of Correction in the same city, there were in five years (1850–1854) 3037 prisoners, of whom 43 died, or 14 per 1000, and of these 24, or 7·9 per 1000, died of phthisis. The comparative length of sentences is not given, but no correction on this ground, if needed, could account for this discrepancy. The great prevalence of phthisis in some of the Indian jails appears to have been owing to the same cause, combined with insufficient diet.

The now well-known fact of the great prevalence of phthisis in most of the European armies (French, Prussian, Russian, Belgian, and English) can scarcely be accounted for in any other way than by supposing the vitiated atmosphere of the barrack-room to be chiefly in fault. This is the conclusion to which the Sanitary Commissioners for the army came in their celebrated report. And if we must also attribute some influence to the pressure of ill-made accoutrements, and to the great prevalence of syphilis, still it can hardly be doubted that the chief cause of phthisis among soldiers has to be sought somewhere else, when we see that with very different duties, a variable amount of syphilis, and altered diet, a great amount of phthisis has prevailed in the most varied stations of the army, and in the most beautiful climates; in Gibraltar, Malta, Ionia, Jamaica, Trinidad, Bermuda, &c. (see history of these stations), in all which places the only common condition was the vitiated atmosphere which our barrack system everywhere produced. And, as if to clench the argument, there has been of late years a most decided decline in phthisical cases in these stations, while the only circumstance which has notably changed in the time has been the condition of the air. So also the extraordinary amount of consumption which has prevailed among the men of the Royal and Merchant Navies, and which, in some men-of-war, has amounted to a veritable epidemic, is in all probability attributable to the faulty ventilation.*

The deaths from phthisis in the Royal Navy averaged (3 years) 2·6 per 1000 of strength, and the invaliding 3·9 per 1000. The amount of consumption and of all lung diseases was remarkably different in the different ships. These inferences have received the strongest corroboration from the outbreak of a lung disease leading to the destruction of lung tissue in several of the ships on the Mediterranean station in 1860. Dr Bryson traces this clearly to contamination of the air, and notices that in several cases the disease appeared to be propagated from person to person.† It may be inferred that pus cells were largely thrown off during coughing, and, floating through the air, were received into the lungs of other persons.

The production of phthisis in animals confirms this view. The case of the monkeys in the zoological gardens, narrated by Dr Arnott, is a striking instance. Cows in close stables frequently die from phthisis, or at any rate from a destructive lung disease (not apparently pleuro-pneumonia); while horses, who in the worst stables have more free air, and get a greater amount of exercise, are little subject to phthisis. But not only phthisis may reasonably be considered to have one of its modes of origin in the breathing an atmosphere contaminated by respiration, but other lung diseases, bronchitis and pneumonia, appear also to be more common in such circumstances. Both among seamen and civilians working in confined close rooms, who are otherwise so differently circumstanced, we find an excess of the acute lung affections. The only circumstance which is common to the two classes is the impure atmosphere. (Compare especially Gavin Milroy and Greenhow.) The favourite belief that these diseases are caused by transitions of temperature and exposure to weather, has been carried too far.

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* Statistical Reports on the Health of the Navy, and especially Gavin Milroy's pamphlet on the Health of the Royal Navy, 1862, pp. 44 and 54.

† Trans. of the Epidem. Soc. vol. ii. p. 142.

In addition to a general impaired state of health, arising, probably, from faulty aëration of the blood, and to phthisis and other lung affections which may reasonably be believed to have their origin in the constant breathing of air vitiated by the organic vapours and particles arising from the person, it has long been considered, and apparently quite correctly, that such an atmosphere causes a more rapid spread of several specific diseases, especially typhus exanthematicus, plague, small-pox, scarlet fever, and measles. This may arise in several ways; the specific poison may simply accumulate in the air so imperfectly changed, or it may grow in it (for though there may be an analogical argument against such a process, it has never been disproved, and is evidently not impossible); or the vitiated atmosphere may simply render the body less resisting or more predisposed.

(*b*) *Air rendered Impure by Exhalations from the Sick.*—The air of a sick ward, containing as it does an immense quantity of organic matter, is well known to be most injurious. The severity of many diseases is increased, and convalescence is greatly prolonged. This appears to hold true of all diseases, but especially of the febrile. At a certain point of impurity, erysipelas and hospital gangrene appear. The occurrence of either disease is, in fact, a condemnation of the sanitary condition of the ward. It has been asserted that hospital gangrene is a precursor of exanthematic typhus,* but probably the introduction at a particular time of the specific poison of typhus was a mere coincidence. But, doubtless, the same foul state of the air which aids the spread of the one disease would aid also that of the other.

When hospital gangrene has appeared, it is sometimes extremely difficult to get rid of it. Hammond† states that in a ward of the New York City Hospital, where hospital gangrene had appeared, removal of the furniture and patients did not prevent fresh patients being attacked. Closing the ward for some time and whitewashing had no effect. The plastering was then removed, and fresh plaster applied, but still cases recurred. At last the entire walls were taken down and rebuilt, and then no more cases occurred.

It is now well known that by the freest ventilation, *i.e.*, by treating men in tents or in the open air, hospital gangrene can be entirely avoided.‡ The occurrence of hospital gangrene in a tent is a matter of the rarest occurrence.

(*c*) *Air rendered Impure by Combustion.*—Of the products of combustion which pass into the general atmosphere (see page 105), the carbonic acid and carbonic oxide are so largely and speedily diluted that it is not likely they can have any influence on health. The particles of carbon and tarry matter, and the sulphurous acid, must be the active agents if any injury results. It has been supposed that molecular carbon and sulphurous acid, instead of being injurious, may even be useful as disinfectants, and we might *a priori* conclude that to a certain extent they must so act, but certainly there is no evidence that the smoky air of our cities, or of our colliery districts, is freer from the poisons of the specific diseases than the air of other places. It has been supposed, indeed, that the air of large cities is particularly antagonistic to malaria, but there are probably other causes acting here. The solid particles of carbon, and the sulphurous acid gas, may, on the other hand, have injurious effects. It is not right to ignore the mechanical effect of the fine powder of coal so constantly drawn into the lungs, and even the possibility of irritation of the lungs from sulphurous acid. Certain it is, that persons with bronchitis and emphysema often feel at once the entrance into the London atmosphere; and individual experience will, I believe, lead to the opinion that such an atmosphere has some effect in originating attacks of bronchitis, and in delaying recovery. But statistical evidence of the effect of smoky town atmospheres in producing lung affections on a large scale cannot be given, so many are the other conditions which complicate the problem.

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* See Guillemin, Recueil de Mémoires de Med. Ch. and Pharm. Militaires, No. 159. 1874.

† On Hygiene, p. 172.

‡ See Chapter on Hospitals, and Professor Jüngken's Address on Pyæmia in the Sydenham Society Year-Book for 1862, p. 213, and Report on Hygiene, by the Author, in the Army Medical Report for 1862 (vol. iv.)

The effect of breathing the products of combustion, of gas especially, is more easily determined. In proportion to the amount of contamination of the air, many persons at once suffer from headache, heaviness, and oppression.

Bronchitic affections are frequently produced, which are often attributed to the change from the hot room to the cold air, but are really probably owing to the influence of the impure air of the room on the lungs.

The effects of constantly inhaling the products of gas combustion may be seen in the case of workmen whose shops are dark, and who are compelled to burn gas during a large part of the day; the pallor, or even anæmia and general want of tone which such men show, is owing to the constant inhalation of an atmosphere so impure.

(*d*) *Air rendered Impure by the Gas and Effluvia from Sewers and House Drains.*—Cases of asphyxia from sulphuretted hydrogen, sulphide of ammonium, carbonic acid, and nitrogen (or possibly rapid poisoning from organic vapours), occasionally occur both in sewers and from the opening of old cesspools. In a case at Clapham, the clearing out of a privy produced in twenty-three children violent vomiting and purging, headache, and great prostration, and convulsive twitchings of the muscles. Two died in twenty-four hours. ("Health of Towns Report," vol i. p. 139.)

These are instances of mephitic poisoning in an intense degree; but when men have breathed the air of a newly opened drain in much smaller amounts, marked effects are sometimes produced; languor and loss of appetite are followed by vomiting, diarrhœa, colic, and prostration. The effluvia which have produced these symptoms are usually those arising from a drain which has been blocked for some time. When the air of sewers penetrates into houses, and especially into the bed-rooms, it certainly causes a greatly impaired state of health, especially in children. They lose appetite, become pale and languid, and suffer from diarrhœa; older persons suffer from headaches, malaise, and feverishnesss; there is often some degree of anæmia, and it is clear that the process of aëration of the blood is not perfectly carried on.*

In some cases I have known decided febrile attacks lasting three or four days, and attended with great headache and anorexia. Houses into which there has been a continued escape of sewer air have been so notoriously unhealthy that no persons would live in them, and this has not been only from the prevalence of fever, but from other diseases. Dr Marston (late R.A.), in his excellent paper on the Fever of Malta,† tells us that when typhoid fever broke out at the Fort of Lascaris, from the opening of a drain, other affections were simultaneously developed, viz., "diarrhœa, dysentery, slight pyrexial disorders, and diseases of the primary assimilative organs." A close examination and analysis of the affections produced by the inhalation of sewer air, would probably much enlarge this list; and the class of affections resulting from this cause, to which it may be difficult to assign a nosological name, will be found, I believe, to be essentially connected with derangement of the digestive rather than with the pulmonary system.

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* Health of Towns Report. See especially the evidence of Rigby, vol. i. p. 151, and of Aldis, vol. i. p. 115.

† Army Med. Report for 1861, p. 486.

Dr Herbert Barker* has attempted to submit this question to experiment by conducting the air of a cesspool into a box where animals were confined. The analysis of the air showed the presence of carbonic acid, sulphuretted hydrogen, and ammonium sulphide. The reaction of the gas was usually neutral, sometimes alkaline. The gas was sometimes offensive, so that organic vapours were probably present; but no analysis appears to have been made on this point. Three dogs and a mouse were experimented on; the latter was let down over the cesspool, and died on the fifth day. The three dogs were confined in the box; they all suffered from vomiting, purging, and a febrile condition, which, Dr Barker says, "resembled the milder forms of continued fever common to the dirty and ill-ventilated homes of the lower classes of the community." But the effects required some time, and much gas for their production. Dr Barker attributes the results, not to the organic matter, but to the mixture of the three gases, carbonic acid, sulphuretted hydrogen, and sulphide of ammonium, and specially to the latter two.

The effect on the men who work in sewers which are not blocked, or temporarily impure from exceptional disengagement of sulphuretted hydrogen from any cause,† has been subject to much debate. The air in many sewers in London is not very impure; the analyses of Letheby and Miller have shown that generally the amount of carbonic acid is very little in excess of that in the external air, and that there is hardly a trace of sulphuretted hydrogen, or of fœtid organic effluvia. The air in the house drains is often, in fact, more impure than that of the main sewers. This is the case also in other places, and is to be accounted for by the numerous openings in the sewers, from the porosity of the walls, from the continual ventilation produced by the air being drawn into houses, and from the amount of water in the sewers being often so great, and its flow so rapid, as to materially lessen the chances of generation of gas. The evidence is, on the whole, opposed to the view that sewer-men suffer in health in consequence of their occupation. Thackrah states‡ that sewer-men are not subject to any disease (apart from asphyxia), and are not short-lived. He cites no evidence. Parent-Duchâtelet§ came, on the whole, to the same conclusion as regards the sewer-men of Paris in 1836. He says that there are some men so affected by the air of sewers that they can never work in them; but those who can remain suffer only from a little ophthalmia, lumbago, and perhaps sciatica. They consider otherwise their occupation not only innocent, but as favourable to health. The only fact adverse to this seemed to be that the air of the sewer greatly aggravated the venereal disease, and those who persisted in working with disease on them inevitably perished. The working in deep, old sewage matter produced an eruption on the parts bathed by the mud, which resembled itch sometimes, or was phlyctenoid in character.

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* On Malaria and Miasmata, 1863, p. 176, *et seq.*

† Fatal cases have occurred both in London and Liverpool sewers from the rapid evolution of $SH_2$, either from gas liquid, or, in Liverpool, from the action of acids passing into the sewers, and meeting with sulphide of calcium in the refuse derived from alkali manufactories.

‡ The Effects of Arts, Trades, and Professions on Health, 1832, p. 118.

§ Hygiène Publique, vol. i. p. 247 (1836). The conclusion of Parent-Duchâtelet are not entirely justified by his evidence. The number of men he examined was small, and many of them had been employed for a short time only in the sewers; it also appeared that a considerable number had actually suffered from bilious and cerebral affections. (See the former editions of this work.)

An inquiry lately conducted into the health of the sewer-men in London did not detect any excess of disease among them,* and I was informed that in Liverpool also the sewer-men have good health. The workmen employed at the various sewage outfalls, and who, though not in the sewers, breathe the effluvia arising from the settling tanks, do not find it an unhealthy occupation.

It does not appear, therefore, that at present the workmen connected with fairly ventilated sewers show any excess of disease; at the same time, it must be allowed that the inquiry has not been very rigorously prosecuted, and that the length of time the men work in sewers, their average yearly mortality, discharge from sickness, loss of time from sickness, and the effect produced on their expectation of life, have not been perfectly determined.

The air of sewers passing into houses aggravates most decidedly the severity of all the exanthemata—erysipelas, hospital gangrene, and puerperal fever (Rigby); and it has probably an injurious effect on all diseases. That pneumonia may be produced is shown by the case of the East Sheen School.

Two special diseases have been supposed to arise from the air of sewers and fæcal emanations, viz., diarrhœa and typhoid (enteric) fever.

With regard to the production of diarrhœa from fæcal emanations, it would seem that the autumnal diarrhœa of this country is intimately connected with temperature,† and usually commences when the thermometer is persistently above 60°, and when there is, at the time, a scarcity of rain-fall. It is worst in the badly-sewered districts, and is least in well-drained districts, and in wet years. It has been checked in London by a heavy fall of rain. All those points seem to connect it with fæcal emanations reaching a certain rapidity of evolution in consequence of high temperature, deficient rain, and perhaps relative dryness of the atmosphere. At the same time, there is a connection between this disease and impure water. It may own a double origin, and in a dry season both cases may be in operation.

That enteric fever may arise from the effluvia from sewers is a doctrine very generally admitted in this country, and is supported by strong evidence. There are several cases on record in which this fever has constantly prevailed in houses exposed to sewage emanations, either from bad sewers or from want of them, and in which proper sewerage has completely removed the fever.‡ Many of these cases occurred before the water-carriage of typhoid was recognised, but yet the connection between the sewage emanation and the fever seem undoubted.

This evidence is supported by cases in which the opening of a drain has given rise to decided typhoid fever,[*] as well as to a very fatal disease (probably severe typhoid), in which coma is a marked symptom. So also in some instances (Windsor and Worthing)[†] the spread of enteric fever has evidently been owing to the conveyance of effluvia into houses by the agency of unventilated sewers. In a case mentioned to me by a friend, an outbreak of enteric fever in a training-school was localised in certain parts of the school (whereas the drinking water was common to all), and was traced to imperfection of traps in those parts of the house which were affected. In this case the drains led down to a large tank at some distance, and at a much lower level, and the smell of the effluvia was so slight that at first it was not believed that the drains could be out of order. A very good case is given by Surgeon Page,[‡] of the 6th Dragoons, in his description of an outbreak of typhoid fever at Newbridge, following discontinuance of the use (on account of repairs) of a ventilating shaft for the sewers. Sewer-gas got into the barracks, and several cases (some fatal) of typhoid fever occurred. Other possible causes were carefully inquired into and eliminated.[§] These two classes of fact seem decidedly to show a causal connection between the effluvia from sewers and excreta and enteric fever, and they are supported by the statistical evidence which proves that the prevalence of typhoid fever stands in a close relation to the imperfection with which sewage matters are removed.[||] The army statistics give excellent instances of this, and the evidence produced by Dr Buchanan of the prevalence of typhoid fever before and after sewerage of a town is to the same effect.[¶]

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* In reference to this point, however, a writer in the Lancet (April 1872) very justly pointed out that the statistics are very imperfect, in taking no notice of men who have been discharged or who have died.

† Ransome and Vernon, Influence of Atmosph. Changes on Dis. p. 3.

‡ In Health of Towns Reports and Evidence, Mr Simon's Reports, Dr Letheby's Reports, Dr Acland's Reports on Fevers in Agricultural Districts, and the Reports of the Medical Officer to the Privy Council, will be found abundant evidence in support of this assertion. Many provincial towns in England could give similar evidence, as Norwich. (See Dr Richardson's Report, Medical Times and Gazette, Jan. 1862). The case of Calstock, in Devonshire, may be also noted. It used to be always liable to outbreak of typhoid fever, but after the drainage of the place the fever disappeared. (Bristowe in Trans. of Epid. Soc. vol. i. p. 396.) Murchison has not only adopted this view, but has proposed to give the term "pythogenic fever" to typhoid.

It seems difficult not to admit that the effluvia from the sewers will produce typhoid, and yet there are some remarkable facts which can be cited on the other side.

It has been denied by Parent-Duchâtelet and by Guy[**] that typhoid fever is more common among sewer-men than others, and late inquiries among the sewer-men of London seem to bear out the assertion. But, as already stated, the air of London sewers is really tolerably pure; and some of the men may be protected by previous attacks, for typhoid fever is a most common disease among the poorer children in London. Murchison[*] and Peacock also state, on the other side, that enteric fever is not uncommon among sewer-men. This argument, therefore, is not of great weight.

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[*] The cases of Croydon, Peckham, Westminster, Fleet Lane, Hammersmith, and Malta are here referred to. See Murchison on Fevers, p. 436, *et seq.* The Hammersmith case is one mentioned by Babington (British Medical Journal, May 3, 1862). The case at Malta is mentioned by Marston (Army Medical Report for 1861, p. 486). I have been informed of a similar case; and it was also affirmed that the evacuations of some patients with typhoid fever had been received two years before into the drain. Riecke (Der Kriegs und Frieden-Typhus, 1850, p. 51) has collected many cases; so also Gietl (Die Ursachen des Ent. Typh. in Munich, 1862). In a case recorded by Dr Buzzard (Lancet, Nov. 1868), a rain water pipe communicating with the discharge pipe of a closet led the effluvia into the house; seven persons out of forty were attacked. Dr Orton of Newcastle-under-Lyne has recorded an outbreak in that city (Med. Times and Gazette, April 1872), arising from sewer gas; no case of typhoid had occurred in the town for some time, and the water was above suspicion. Dr Fergus of Glasgow, who has paid great attention to the conditions of water-closet and sink pipes, and has pointed out how rapidly they decay and get out of order, has noted several cases. In a case at Preston, recorded in the Medical Times and Gazette, Feb. 10, 1872, the gas forced back in a drain by the rise of a river, into which the drain opened, caused typhoid fever in several persons. In Croydon, in 1866, Buchanan mentions that the sewer gases were forced noisily back the traps of water-closets in several houses, in which outbreaks of typhoid occurred a few days afterwards.

[†] Ninth Report of Medical Officer to Privy Council, p. 44.

[‡] Army Med. Report. vol. xv. p. 301.

[§] An outbreak at Kinsale, apparently due to sewer effluvia, is narrated by Surgeon-Major Wallace, Army Med. Reports, vol. xvii. p. 55. The inquiry seems to have been very carefully made.

[||] The Medical Inspectors of the Privy Council are fully alive to the occasional propagation of typhoid fever by water, and yet the doctrine that the disease can be conveyed in the air is firmly held by them, and few men have more experience. (See Mr Netten Radcliffe's Report on Fever at Bradford in 1872.) Greisinger also has no doubt, from a large experience, of the origin of typhoid fever in this way.

[¶] Ninth Report of Medical Officer to the Privy Council, p. 44. In 21 English towns the average reduction of typhoid mortality after sewage was 45·4 per cent. In many of the towns an improved water supply was introduced at the same time, but the purification of the air by sewerage and cleanliness has, it is believed by Buchanan, "been most uniformly followed by a fall in the prevalence of typhoid."

[**] Journal of the Statistical Society, 1848.

The evidence is very strong that the men employed at the sewage tanks and on the sewage farms, and their families, do not show an unusual amount of typhoid; nor do the persons living in adjacent houses. Now, if sewage emanations can cause typhoid fever, it might be expected that we should by this time have had plenty of evidence of this special effect. Again, in our rural villages, and in many farm houses, the excreta of men and animals literally cover the ground, and it might have been anticipated that enteric fever would never be absent. If this is the case in this country, it is still more so in China, where the excreta are so carefully stored and applied to land. In the late reports made by various medical officers in the *Customs Gazette of China* for 1871, the writers state that, in Chinese villages surrounded with excreta, and where the contamination of the air by fæcal emanations is very great, there is no typhoid fever. And as typhoid is well known in other parts of China, the absence is not owing to any peculiarity of climate preventing the appearance of the fever.[†]

We have, then, counterfacts which must be allowed to be of considerable weight. Any explanation, to be satisfactory, must not ignore one set of facts, but must impartially include both.

The possibility that the adult persons submitted to sewage emanations may have had typhoid fever in early life, and are therefore insusceptible, may explain some cases of escape, even when fæcal emanations are constantly breathed. But it would be impossible to extend this argument to the cases of immunity in children, unless we suppose that typhoid fever in children is constantly overlooked, and is as common as measles, which seems very unlikely.

It has been supposed that there is an essential difference when animal and vegetable substances are decomposing in covered places and in the open air.[‡] It is evident that the physical conditions will be widely different in the two cases. In underground channels there is greater mean temperature, more moisture, and a more stagnant atmosphere. In the open air, while there may be heat from the sun's rays, this may restrain putrefaction; while the coldness of the nights, and the much greater movement and dryness of the air, may hinder the formation or lessen the chance of reception of any fever-causing substance developed during the putrefaction. At first sight, there appears to be much in favour of this view, and it would explain the greater chance there appears to be of effluvia coming from sewers causing typhoid fever than when the effluvia came from excreta in the open air. But it does not meet two undoubted facts, viz., that there are cases in which sewer air is breathed without causing typhoid, and the occasional severe outbreaks of typhoid in villages without sewers, and where there is no putrefaction under cover.

That the importation of typhoid fever into places previously free for years is followed by outbreaks[§] is quite certain. In many of these cases, as in the excellent instance at Steyning, recorded by Whitley,[*] all the conditions of accumulated sewage, &c., which are supposed to produce typhoid fever, were present for years, and yet no fever resulted. Then a patient came from a distance with typhoid fever, and the disease spread through the village, either through the medium of the water (as is perhaps most common), or through the air. These instances are so numerous that the entrance of a fresh agent must be admitted, and if so, the series of events becomes quite intelligible.

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[*] On Fevers, p. 453.

[†] See Reports by Drs Miller and Manson, for Shanghai and Amoy, in the Customs Gazette, July-Sept. 1871.

[‡] This is the view taken in the Second Report of the State Board of Health of Massachusetts. From an inquiry in most of the large cities of that state, the conclusion is drawn that it is putrefaction of animal and vegetable substances, *under cover*, which gives typhoid.

[§] The cases recorded fifty years ago by Bretonneau have been confirmed by many observations since.

The doctrine that a specific cause is necessary for the production of typhoid fever; that this cause is present in the intestinal discharges,[†] and that sewers and fæcal effluvia, and fæcal impregnation of water, are thereby the channels by which this specific cause reaches the body of a susceptible person (*i.e.*, of a person who has not previously had the disease), will be found to explain almost all the events which have been recorded in connection with the origin of typhoid fever.

There are, however, still some difficulties. There are instances in which typhoid fever arises from sewer air without any possibility of tracing the entrance of a person with the disease.[‡] Sometimes, as in the case of an isolated house in the country, it seems most difficult to believe that any such entrance could have taken place. It must, however, be remembered that the carriage of the "contagion" takes place in so many ways, that it is impossible always to trace it. In the case of typhoid fever, the stools are not only infectious during the height of the disease, but probably during the early period of recovery;[§] and the disease itself is also often so slight that persons move about, and believe they have only an attack of diarrhœa. Again, the frequent journeying from place to place exposes all persons to a greater chance of inhaling the typhoid effluvia, and the real source of the disease may be far removed from the place which is actually suspected.

There are, again, cases in which typhoid fever occurs in persons who have not been exposed apparently to sewer air, or fæcal emanations, or to the charge of any typhoid contagion. Dr Gordon Hardie has recorded two cases of this kind of soldiers attacked during imprisonment. Such cases can only be explained either by supposing an incubative period of extraordinary length, or an origin apart altogether either from fæcal emanations or a prior case of the disease.

Admitting, however, that there are still difficulties to be explained by future observation, it seems clear that the theory of a specific cause reproducing itself in the intestines and contained in the discharges, and naturally, therefore, connected more or less closely with excreta and sewers, and sometimes with drinking-water, is that which best meets the facts which have been most faithfully reported in outbreaks of typhoid fever. The evidence of the carriage of a cause of this kind in water strongly supports this view.

(*e*) *Emanations from Fæcal Matter thrown on the Ground.*—Owing, doubtless, to the rapid movement of the air, there is no doubt that the excreta of men and animals thrown on the ground and exposed to the open air are less hurtful than sewer air, and probably in proportion to the dilution.

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[*] From the Report of the Medical Officer to the Privy Council, p. 43.

[†] That the effluvia from the typhoid stools will produce typhoid fever seems to be certain, and a good case is given by Riecke. The evacuations of a typhoid patient were placed in an outhouse, the upper room of which had an unceiled floor. Two men who had no intercourse whatever with the patient, and never entered the house, but who slept in the upper room, were attacked, and at the same time.

[‡] Ranke admits the possibility of spontaneous orgin of typhoid, but thinks it spreads more frequently through air than any other way.

[§] In a case (under the care of Dr Langstaft of Southampton), the patient died after 17 weeks' illness; his brother was attacked with typhoid fever about a week before the death of the other, and no other source of the disease, except visiting his brother, could be traced. Accordingly, allowing the longest known period of incubation (21 days), the disease must have been communicated in the 13th week of illness. The case, although not decisive, is curious.

When there are accumulations in close courts, small back-yards, &c., the same effects are produced as by sewer air, and many instances are recorded in the "Health of Towns Reports." When fæcal matters are used for manure, and are therefore speedily mixed with earth, they seldom produce bad effects. Owing, doubtless, to the great deodorising and absorbing powers of earth, effluvia soon cease to be given off. An instance is, however, on record in which two cases of typhoid were supposed to arise from the manuring of an adjacent field. Dr Clouston has also shown by evidence, which seems very strong, that dysentery was produced in an asylum by the exhalations from sewage, which was spread over the ground (a stiff brick clay subsoil) about 300 yards from the asylum. The case seems a very convincing one, as the possibility of the action of other causes (impure water, bad food, &c.,) was excluded. This is a point on which more evidence is desirable. It is stated in some works that disease is frequently produced by the manuring of the ground, but I have been able to find no satisfactory evidence. It has been said that if the sewage matter can be applied while perfectly fresh to the ground, no harm results; but if decomposition has fully set in, it is not so completely deodorised by the ground. (See chapter on Sewage.) In China, where fæcal matter is so constantly applied in agriculture, the air is often filled with very pungent effluvia, yet no bad effect is produced. (See Dr A. Jamieson's "Report on the Health of Shanghai for the half-year ending September 1870," *China Customs Gazette* for 1870; Shanghai, 1871.)

(*f*) *Emanations from Streams polluted by Fæcal Matter.*—The evidence on this point is contradictory. Parent-Duchâtelet, in 1822,[*] investigated the effect produced on the health of the inhabitants of the Faubourg St Marceau, in Paris, by the almost insupportable effluvia arising from the Rivière de Bièvre, which received a large portion of the sewage of the quarter. He asserts that the health was not at all damaged, though he admits that there is truth in the old tradition at the Hôtel Dieu, that the cases from St Marceau were more severe than from any other place.

Dr M'William found that the emanations from the Thames in 1859–60 had no deleterious effect on the health of the Custom-House men employed on the river. The amount of diarrhœa was even below the average.

Mr Rawlinson states ("Report of Committee on Sewage," 1864, p. 174, Question 3997) that a careful house to house visitation had been made in some of the worst districts of Lancashire (in Manchester, on the banks of the Medlock, for instance) without finding any great excess of disease.

On the other hand, in the reports of Sir H. De la Beche and Dr Lyon Playfair,[†] is some strong evidence that the general health of the people suffered from the emanations of the putrid streams of the Frome, and the tributaries of the Irk and Medlock; that they were pale, in many cases dyspeptic; that fevers (typhoid) prevailed on the banks is asserted by some observers, but rather doubted by others; but none seem to have any doubt that the fevers, when they occurred, were much worse. Cholera in Manchester was severe along the banks of some of these streams, but that might have been from the water being drunk. In 1858 also, Dr Ord[*] observed that a large number of the men employed on the Thames were affected by the effluvia; the symptoms being languor and depression, followed by nausea and headache, aching of the eyeballs and redness and swelling of the throat. Diarrhœa was rare. In 1859 these symptoms were not observed, though the state of the river was worse. Were they then really caused by the effluvia in 1858?

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[*] Hygiène Publique, p. 98.

[†] Second Report of the Health of Towns Commission, pp. 261 and 347. Lyon Playfair says, "The medical men in Manchester whom I have consulted are unanimously of opinion that the emanations from the putrid streams which wind their way sluggishly through the town are a cause of disease and mortality." On the other hand, Whitehead (Rate of Mortality in Manchester, 3d edit. 1864, p. 50) denies that typhus (typhoid ?) is more prevalent near the banks of these streams, and also denies (p. 52) that health is injuriously affected. Mr Rawlinson also (Report of Sewage Committee, 1864, p. 174, Question 3997) states that no great excess of disease from exhalations was found to exist on the banks of the Medlock. So also the state of the Clyde, which is at the present very bad, produces no effect whatever on health. (See Glasgow Medical Journal for Nov. 1868; also the Sewage Question, by Dr Fergus, 1874, p. 25.)

It is very likely that the discrepancy of evidence may arise from the amount of water which dilutes the fæcal matter being much greater in some cases than others. In the case of the Thames, the dilution was after all very great, and this was the case, in part at any rate, in the Bièvre, as the stream was in some places 6 and 7 feet deep. The evaporation from such a body of water, however offensive it may be, must be a very different thing from the effluvia coming off from the masses of organic matter laid bare by the almost complete drying up of streams into which quantites of fæcal matter are poured. When sewage matter is poured into the sea, and washed back by the tide, it may become a source of danger. An epidemic of enteric fever occurred in this way among the recruits of the Royal Marine Artillery, who were employed to build a sea-wall at Fort Cumberland, to protect Langston Harbour (near Portsmouth). An outbreak took place, which could not be accounted for by anything in the quarters, food, or water supply. The sewage of Portsmouth is pumped into the sea near that spot, but the pumping ought to take place at ebb-tide only; it was found that this rule had been neglected, and that pumping had taken place during the flow, so that the sewage was carried back and deposited on the mud where the work was taking place. Out of 130 recruits, 4 died, 16 had distinct attacks of enteric fever, and 40 had milder attacks of indisposition. Cases also occurred at Hilsea Barracks, further up the harbour.

(*g*) *Effect of Manure Manufactories.*—The manure manufactories at present existing in this country do not appear to produce any bad effects. They are generally at some little distance from towns, and the effluvia are soon diluted. The Secretary of the Hyde Manure Company informed me that while the works were in operation no bad effects were produced. But if situated in towns they are nuisances, and may be hurtful. In 1847 evidence was given to show that a manure manufactory situated in Spitalfields, and about 100 feet from the workhouse, caused bad diarrhœa whenever the wind blew in that direction, and 12 cases of "spontaneous gangrene" (!) which had appeared among children were attributed to it. The cases of disease in the workhouse infirmary also acquired, it was said, a malignant and intractable character.[†] In France the workmen engaged in the making of "poudrette" do not in any way suffer, except from slight ophthalmia.[‡] Parent-Duchâtelet[§] (on very slight evidence indeed) thought the emanations were even beneficial in some diseases, and Tardieu seems inclined to support this opinion. The Secretary of the Hyde Manure Company informed me that some of the men appeared actually better in health. When the poudrette is decomposing, and large quantities are brought into small spaces, as on board ship, serious consequences may certainly result. Parent-Duchâtelet records two cases of outbreaks on board ships carrying poudrette which fermented on the voyage; one vessel, the "Arthur," lost half her crew (number not known), and the rest were in a state of deplorable health; the men who unloaded the cargo were also affected. The symptoms are not recorded, but, in a smaller vessel, where all on board (5) were similarly affected, the disease put on the appearance of "an adynamic fever." There was intense pain of the head and of all the limbs, vomiting, great prostration, and in two cases great diarrhœa. These symptoms are very similar to those already mentioned as produced in the children at Clapham by the opening of a privy.

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[*] Trans. Social Science Association, 1859, p. 571.

[†] Medical Gazette, December 1847.

[‡] Parent-Duchâtelet; Patissier. See also Tardieu, Dict. d'Hygiène, t. iv. p. 453. Tardieu, in 1862, writes—"We do not hesitate to affirm that the exhalations from these manufactories (voiries) exercise no injurious action either on man or vegetation." But it must be remembered that these places are excellently conducted; ventilation is good, and the fæcal matter is soon subjected to processes which prevent its decomposition.

[§] Hyg. Publique, t. ii. p. 276.

(*h*) *The Air of Graveyards.*—There is some evidence that the disturbance of even ancient places of sepulture may give rise to disease. Vicq d'Azyr refers to an epidemic in Auvergne caused by the opening of an old cemetery; the removal of the old burial-place of a convent in Paris produced illness in the inhabitants of the adjoining houses.* In India, the cantonment at Sukkur was placed on an ancient Mussulman burial-ground, and the station was most unhealthy,† especially from fevers.

The effect of effluvia from comparatively recent putrefying human bodies has been observed by many writers. Rammazzini‡ states that sextons entering places where there are putrefying corpses are subject to malignant fevers, asphyxia, and suffocating catarrhs; Fourcroy remarks that there are a thousand instances of the pernicious effects of cadaveric exhalations; and Tardieu§ has collected a very considerable number of cases, not only of asphyxia, but of several febrile affections produced by exhumations and disturbance of bodies. Mr Chadwick,‖ and the General Board of Health,¶ have also summed up the recent evidence, which shows that in churchyards thickly crowded with dead, vapours are given off which, if not productive of any specific disease yet increase the amount both of sickness and mortality. In some instances, this may be from contamination of the drinking water; but in other cases, as in the houses bordering the old city graveyard, where the water was supplied by public companies, the air also must have been in fault. In the houses which closely bordered the old city yards, which were crowded with bodies, cholera was very fatal in 1849,** and I was informed by some practitioners that no cases recovered. I was also informed that all other diseases in these localities assumed a very violent and unfavourable type. Hirt says, on the other hand, that when gravediggers are protected from the acute effects of carbonic acid their calling is not unhealthy.

(*i*) *Effluvia from Decomposing Animals.*—On this point there is some discrepancy of evidence.

In 1810, Deyeux, Parmentier, and Pariset, gave evidence to show that the workmen in knackeries are in no way injured. Parent-Duchâtelet, from his examination of the health of the men employed at the knackery and slaughter-house at Montfaucon, came also to the conclusion that their health was not affected. It should be mentioned that this knackery is remarkably well placed for ventilation, and is excellently conducted; putrid remains, in the proper sense of the word, do not now exist in any knackery in or near Paris; the workmen are well paid and well fed, and are therefore prepared to bear the effect of any injurious effluvia. It has been stated, however, that in the Hôtel Dieu, the patients used to suffer when the wind, loaded with effluvia, blew from Montfaucon (Henry Bennet). Tardieu, from a late re-examination of the question, confirms Parent's conclusions,* except as regards glanders and malignant pustule, touching which Parent-Duchâtelet's evidence was as usual negative. Tardieu (t. iv. p. 468), however, states that many examples occur in the French knackeries of the transmission of these diseases, though glanders and farcy are less frequently caught in knackeries than in stables. No analysis has yet been made of the air of knackeries.

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* Tardieu Dict., d'Hygiène, i. p. 517.

† Norman Chevers, European Soldiers in India, p. 404.

‡ Maladies des Artizans, p. 71.

§ Dict. d'Hygiène, 1862, t. iii. p. 463, *et seq.*

‖ Report on Interments in Towns.

¶ Report on Extramural Sepulture, 1850.

** S. Smith, and Sutherland's Reports on Extramural Interment, p. 12. See also Sutherland's Report on Cholera, 1850, p. 27.

Parent-Duchâtelet† is often also quoted, as having proved that the exposure of the remains of 4000 horses killed in the battle of Paris in 1814, produced no bad effects. These horses were killed on the 30th March, and were burnt on the 10th and 12th of April. They gave out "une odeur infecte," which produced no bad results on those who collected the bodies. Parent-Duchâtelet inquired particularly whether typhus was produced by the effluvium, and proved that it was not; a conclusion conformable to our present doctrine. He did not, however, do more than examine the registers of deaths for the three years before, during, and after the battle, and found no evidence of increased mortality. The utmost this observation shows is, that no typhus was produced; and that the amount of decomposition, caused by eleven days of hot weather, did not affect those concerned in collecting and burning the bodies.

On the other hand, the experience of many campaigns, where soldiers have been exposed to the products of an advanced putrefaction of horses, shows that there is a decided influence on health. Pringle especially noticed this; *and in many subsequent campaigns this condition has been one of the causes of insalubrity. Diarrhœa and dysentery are the principal diseases; but all* affections are increased in severity. At the siege of Sebastopol, where, in the French camp, a great number of bodies of horses lay putrefying on the ground, Reynal‡ describes the effect as disastrous, and even conjectures that the spread of typhus was connected with this condition, though this is unlikely.

(*k*) *Air of Brickfields and Cement Works.*—The peculiar smell of brickfields cannot be owing to carbonic acid, carbonic oxide, or to hydrosulphuric acid, or sulphurous acid (the gases evolved from the kilns); but its exact cause, I believe, is not known. The air, at its exit from the chimney of furnaces and kilns, is rapidly fatal; but so rapid is its ascension, dilution, and diffusion, that at a little distance it is respirable. In almost all the actions against the owners of brickfields nothing more than a nuisance has been established. The smoke and gases from cement works, however, destroy neighbouring vegetation. The smell can be perceived for several hundred yards.§ In the north of France it is ordered that no kilns shall be within 50 metres (54½ yards) of a public road; and the kilns are lighted only at night.

(*l*) *Air of Tallow-makers, Boneburners, &c.*—In many trades of this kind large quantities of very disagreeable animal vapours are produced, which spread for a long distance, and are most disagreeable. Although a nuisance, it is difficult to bring forward positive evidence of insalubrity. But the odour is so bad that in France rules are in force to oblige the vapours to be condensed or consumed,‖ and if in the process any water is contaminated with fatty acids, it is neutralised with lime. M. Foucon has figured an apparatus which completely burns the animal vapours.¶

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* Dict. d'Hygiène, t. iv. p. 468.

† Dict. d'Hygiène, t. i. p. 47.

‡ Tardieu, Dict. d'Hygiène, t. ii. p. 221.

§ At Southampton the smell is perceptible at more than a mile.

‖ Vernois, Hygiène Industrielle. t. ii. p. 60.

¶ Pappenheim's Beit. der Sanitat. Pol. Heft. ii.

(*m*) *Air of Marshes.*—It seems scarcely necessary to allude to this point, except to notice that, in addition to paroxysmal fevers, it has been supposed that serous diarrhœa (a sort of dysenteria incruenta) and true bloody dysentery, are produced by malaria. Also that there is perhaps some connection with malaria and liver abscess (?). The breathing of marsh air also may produce an imperfect condition of nutrition, in which enlarged spleen plays a prominent part, and the mean duration of life is shortened.

(*n*) *Unknown Conditions of the Atmosphere.*—Occasionally, outbreaks of disease occur from impurities of the atmosphere, the nature of which is not known, though the causes giving rise to them may be obvious. Dr Majer* records a case of a school at Ulma, of sixty or seventy boys, where the greater number were suddenly affected, on a warm day in May, with similar symptoms—giddiness, headache, nausea, shivering, trembling of the limbs, sometimes fainting. The attack occurred again the next day, and a common cause was certain. The room was enclosed by walls, in a narrow space, where the snow had lain all the winter; the wall was covered with fungous vegetation, and with salts from the mortar. From the sudden entrance of warm weather, fermentation had set in, and a strong marshy smell was produced; the substances of whatever kind generated in this way accumulated in the narrow, ill-ventilated space. Removal to a healthier locality at once cured the disease.

## SECTION III.

## PURIFICATION OF THE AIR BY CHEMICAL METHODS.

The great purifying actions of Nature are diffusion, dilution, transference by winds, oxidation, and the fall of rain. In houses the power of ventilation is the only safe method, but some effect can be produced by chemical agencies in aid of ventilation.

The foreign matters in the air, which can be removed by chemical means, are carbonic acid, sulphuretted hydrogen, ammonia (usually in the form of ammonium sulphide), and various organic substances, arising in an infinity of ways, some being odorous, others not, and of the physical and chemical nature of which little or nothing is known. Air purifiers are also used to check the growth of fungoid or infusorial organisms. They are used in the form of solids or of liquids, which may absorb the substances from the air, or of gases which may pass into the air, and there act on the gases or molecular impurities.

(*a*) *Solid Air Purifiers.*—Dried earth, quicklime, charcoal, and calcium and magnesium carbolates (phenates), a mixture of lime and coal-tar, are the most important.

Of these charcoal is the most effectual. It presents an immense surface, and has a very extraordinary power of separating and absorbing gases and vapours from the atmosphere (Sennebier, quoted by Chevallier, "Traité des Désinfect." p. 146, and A. Smith), and oxidises rapidly almost every substance capable of it. Its action is not indiscriminate, but elective (A. Smith); when charcoal which has absorbed oxygen is warmed, it gives off carbonic acid (A. Smith), a proof of its great oxidising power. Exposed to the air in bags or shallow pans, its action is rapid and persistent; its effect is especially marked with sewage gases, and with the organic emanations in disease. It also absorbs sulphuretted hydrogen. Its power of purifying air from organic emanations is really great, and can be employed in hospital wards with advantage.

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* Canstatt's Jahresb. 1862, vol. ii. p. 32.

Of the different kinds of charcoal, the animal charcoal has the highest reputation, and then peat. But the carbon left in the distillation of Boghead coal has been stated to be even better than animal charcoal. If vegetable charcoal be used, it should be rather finely powdered. The disinfecting qualities of charcoal on air scarcely lessen with time if the charcoal be kept dry. Charcoal filters to be placed before the mouth have been recommended by Stenhouse, and might be useful in cases of very impure air. Dried marly earth is much inferior to charcoal, but still can be employed in the absence of the latter.

Quicklime absorbs carbonic acid, and perhaps compounds of sulphur, and has been employed for that purpose.

Lime and magnesium carbolates have been also used; their exact effect on the air passing over them is not, I believe, known; but as they give off carbolic acid, their action may be chiefly in that way.

(*b*) *Liquid Air Purifiers.*—Solutions of potassium permanganate (Condy's red fluid), zinc chloride, and lead nitrate are sometimes used, being either exposed in flat dishes, or cloths are dipped in the solution and exposed to the air. They act only on the air which comes in contact with them, but in that way absorb a good deal of impurity. Condy's fluid, when well exposed to the air, seems to have a good purifying effect, and to lessen the close smell of ill-ventilated rooms, and it absorbs sulphuretted hydrogen, and so will also solution of nitrate of lead.

Lime and soda chlorides, nitrous acid, solution of sulphurous acid, pyroligneous acid, act on the air chiefly or entirely by the gases which pass off from them, and their effects are considered under that head.

(*c*) *Gaseous Air Purifiers.*—The evolution of gases into the air is the most powerful means of purifying it independent of ventilation. The principal gases are ozone, chlorine, iodine, bromine, nitrous, sulphurous, and hydrochloric acid, carbolic acid, tar fumes, acetic acid, ammonia.

*Ozone.*—It has been proposed to disengage ozone constantly into the air of a room, by heating a platinum wire by a Bunsen cell; by half immersing a stick of phosphorus in tepid water in a wide-mouthed bottle; or by mixing very gradually 3 parts of strong sulphuric acid and 2 parts of permanganate of potassium. This last method is that used by Dr Fox.* The amount of ozone can be measured by the common ozone paper, and the stopper put in if the tint is too deep. It is presumed it will then act as a powerful oxidising agency, and destroy organic matter, as it certainly removes the putrid effluvia of decomposing blood (Wood and Richardson). It has been much used by Dr Moffat in cholera and cattle plague.

*Chlorine.*—Given off from chloride of lime, moistened with water, or with dilute sulphuric acid, and placed in shallow vessels, or from chloride of soda, or evolved at once. Four parts by weight of strong hydrochloric acid are poured on one part of powdered binoxide of manganese, or four parts of common salt and one part of binoxide of manganese are mixed with two parts by weight of sulphuric acid and two of water, and heated gently. According to the size of the room, the actual weight of the substances taken must vary. Or two table-spoonfuls of common salt, two tea-spoonfuls of red lead, half a wine-glassful of sulphuric acid, and a quart of water are taken. Mix the lead and salt with the water, stir well, and add the sulphuric acid gradually. Chlorine is evolved, and is absorbed by the water, from which it is slowly driven out. It may be kept in a jar or stoppered bottle, left open as occasion may require†.

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* Ozone and Antozone, p. 25.

† Medlock's Record of Pharmacy and Therapeutics, 1858, p. 20.

Chlorine decomposes sulphuretted hydrogen and ammonium sulphide at once, and more certainly than any other gas. It doubtless destroys organic matter in the air, as it bleaches organic pigments, and destroys odours, either by abstracting hydrogen, or by indirectly oxidising. Euchlorine, a mixture of chlorous acid and free chlorine, obtained by gently heating (by placing the saucer in warm water), a mixture of strong hydrochloric acid and potassium chlorate, has been also used instead of pure chlorine. It has been strongly recommended by Professor Stone of Manchester, who has devised a special apparatus for its disengagement. He also uses it by placing fuming hydrochloric acid in a wine-glass, and adding a few grains of chlorate from time to time. In that way there is no danger of explosion, as sometimes is the case if a large quantity of chlorate is warmed with hydrochloric acid. The odour of euchlorine is more pleasant than that of chlorine; it acts as rapidly on iodide of potassium and starch paper, and appears to have a similar action on organic substances; whether it is superior or inferior to pure chlorine, I do not know, but the ease of development and its pleasanter smell are in its favour.

*Iodine* can be easily diffused through the atmosphere by placing a small quantity on a hot plate. Dr Richardson proposes to saturate a solution of peroxide of hydrogen with iodine, and to add 2½ per cent. of sea-salt; by "atomising" or "pulverising" the fluid by the little instrument used for this purpose, the air can be charged with iodine and sea-salt spray very readily. Iodine will decompose $SH_2$, and destroys, therefore, much odour. Its action was investigated by Duroy in 1854,* who showed that it is a powerful arrester of putrefaction. As it condenses easily, and does not diffuse everywhere like chlorine, it might be expected to be less useful than chlorine.

*Bromine.*—In the American civil war bromine was rather largely used as an aerial disinfectant; a solution of bromine in bromide of potassium is placed in saucers and exposed to the air; the vapour is, however, very irritating, and should not be disengaged in too large an amount.

*Nitrous Acid* can be evolved by putting a bit of copper in nitric acid and a little water. The nitrogen dioxide which is given off takes oxygen from the air, and red fumes, consisting chiefly of nitrogen tetroxide or nitrous acid ($N_2O_4$), are formed.

The oxidising action of nitrous acid is very great on organic matter. It removes the smell of the dead-house sooner than any other gas. It is rather irritating to the lungs, and, in some persons, large quantities of it cause vertigo, nausea, and even vomiting. If possible, when it is used, the rooms should be cleared; if not, it should be disengaged slowly, which can always be done by diluting the nitric acid.

The action of nitrous acid results from the ease with which it parts with oxygen to any oxidisable substance, being converted into nitrogen dioxide, which again at once combines with atmospheric oxygen, and so on.

*Sulphurous Acid.*—Most easily evolved by burning sulphur. It decomposes sulphuretted hydrogen ($SO_2 + 2SH_2 = 3S + 2OH_2$), and also combines with ammonia. It has also been supposed to act powerfully upon organic matter (Graham), and probably does so if ammonia is not present. Guyton-de-Morveau who studied the action of this acid, was of opinion that it completely disinfects miasms, and gives some evidence on this point. It must be used in large quantity.

*Hydrochloric Acid.*—The fumes of this acid were used by Guyton-de-Morveau, and at one time they were much employed, but the action of chlorine is so much more powerful that they are now seldom used.

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* Chevallier, Traité des Désinfect. p. 19.

*Carbolic Acid.*—This substance is given off when solid carbolic acid is placed in a saucer, or when the liquid acid and water are sprinkled about, or still better, when one part of the acid and two of ether are allowed to evaporate. It is difficult to measure its action, as it decomposes solution of potassium permanganate, which cannot therefore be used as a measure of the organic impurity of air when carbolic acid vapours are present.

Dr Sansom* has shown that when the acid evaporates, 1 grain of carbolic acid is taken up, at different temperatures, by the following amounts of air, viz., by 320·75 cubic inches at 50° Fahr., by 159·44 cubic inches at 60° Fahr., and by 93·75 cubic inches at 70° Fahr. Vaporizers for carbolic acid fumes have been made, by means of which carbolic acid falls, drop by drop, on a hot metal plate.† Dr Langstaff‡ has invented a trough, containing flannel wetted with water and carbolic acid (1 part of acid and 20 of water), which is placed in the inlet ventilating tubes; he finds that at a temperature of 57°, four ounces of water are taken up in 24 hours, and this will keep the air of a room, 22 feet × 10 and 11 feet high, thoroughly impregnated with the odour. Carbolic acid conceals all odours, though it will not destroy sulphuretted hydrogen if it exists; it lessens the rapidity of putrefaction of animal substances suspended in a room, and they also dry faster, according to Langstaff. It also rapidly arrests the growth of fungi, though it will not completely destroy them; for example, I put some fresh fæcal matter, free from urine, in a bottle, and drew air washed in strong sulphuric acid over it; fungi appeared rapidly on the fæcal matter. I then passed air impregnated with carbolic acid over the fungi; they become discoloured, brownish, and apparently died; but on again substituting washed air, they revived. The rapid destruction, and the as rapid recovery and regrowth, could be repeated many times, and showed that the carbolic acid air had withered without actually killing the fungi.

The small growing cells suspended in the air are also stopped in their growth (according to Trautman); and, in fact, the action of carbolic acid may be said to be restraint of putrefaction and limitation of growth of low forms of aerial life.§ The exact mode in which it acts is uncertain. When in some quantity, it coagulates albumen; and it has been supposed to be in this way that it restrains putrefaction.||

A mixture of 1 part of carbolic acid and 9 of vinegar, and a little camphor, has been used as a disinfectant in cabins on board ship.

*Coal-tar and Bitumen Fumes.*—This is an old plan much used in the last century; the fumes contain carbolic and cresylic acids with other substances, and it is presumed have the same effect as carbolic acid. The substance employed by Süvern, and which has at present some reputation in Germany, owes its success as an air-purifier to the fumes of coal-tar.

*Vinegar and Ammonia.*—The vapour of vinegar is an old remedy, and was much employed by Howard in the purification of jails; the efficient agents were probably heat and ventilation, which Howard made use of at the same time. The vinegar would, of course, neutralise any ammoniacal vapours which might be in the air; whether its action would extend beyond this is doubtful.¶

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[*] The Antiseptic System, by A. E. Sansom, M.D., 1871, p. 15.

[†] Savory and Moore's vaporiser is figured by Sansom.

[‡] Hospital Hygiene, by Charles Langstaff, M.D., 1872, p. 20.

[§] Lemaire, Crookes, Sansom, and others.

[||] Various other hydrocarbons probably act in the same way, as, for instance, the terebene proposed by Dr Bond of Gloucester.

[¶] It may perhaps delay putrefaction and the growth of minute organisms.

The vapour of ammonia would not *a priori* seem likely to be a purifier, though, as it restrains decomposition in solid matters, its vapour may have an effect in the air.

It will be observed that the chief gases attacked by the air-purifiers are sulphuretted hydrogen and ammonium sulphide, which are easily destroyed by several agents, especially by chlorine, iodine, and sulphurous acid gas.

The opinion that the floating organic vapours or molecules of whatever kind in the air are destroyed by the air-purifiers, has been hitherto derived not from direct quantitative determination of the organic matter before and after the action of the purifiers, but from their influence on odours and on other organic substances where their action is more easily followed. But the analogical evidence is so strong that we can have little doubt of the reality of the action.

The mode of action of the air-purifiers may be conceived to vary. Ozone and nitrous acid will directly oxidise all substances which can be so acted upon. Chlorine may act by substitution for hydrogen, or it may take hydrogen and oxidise indirectly by liberating oxygen; bromine and iodine may also take hydrogen in the same way. Sulphurous acid more probably deoxidizes and forms sulphuric acid. In other cases, it seems probable that neither substitution nor oxidation nor the reverse takes place, but that the action is one of restraint of putrefaction and of limitation of the growth of cryptogamic life. At least this may be inferred from the experiments of Crookes, Lemaire, and others on the action of carbolic acid on low forms of life growing in liquids. In practically carrying out aerial purification, great care is necessary to ensure that the gas or vapour is diffused everywhere through the room, and that it is constantly present. In a sick-room the vessel from which it is disengaged should be some little distance above the bed, or, in some cases, underneath it. In hospitals with inlet tubes, it should be in the inlet tubes; whatever be the agency, there should be a slight odour always perceptible. In the purification of empty rooms, all apertures should be closed. (SEE chapter on DISINFECTION.)

# CHAPTER III.

# VENTILATION.

The term ventilation is not always used in the same sense. By some it is applied to the dilution and removal of all impurities which can collect in the air of inhabited rooms. The most common causes of such impurities are the respiration and cutaneous transpiration of men, the products of combustion of lights, the effluvia of simple uncleanliness of rooms or persons, the products of the solid or fluid excreta retained in the room, or, in hospital, discharges from the body or from dressings. In addition there may be special conditions which allow impure air to flow into a room, as from the basement of a house, or from impurities outside a house.

It will be desirable, however, to restrict the term ventilation to the removal, by a stream of pure air, of the pulmonary and cutaneous exhalations of men, and of the products of combustion of lights in ordinary dwellings, to which must be added, in hospitals, the additional effluvia which proceed from the persons and discharges of the sick. All other causes of impurity of air ought to be excluded by cleanliness, proper removal of solid and fluid excreta, and attention to the conditions surrounding dwellings.*

The subject of ventilation may be conveniently considered under the following heads :—

1. The quantity of fresh air required for the purposes defined above.
2. The mode in which this quantity may be supplied.
3. The method of examining whether ventilation is sufficient; in other words, whether the air of inhabited rooms is properly pure. This will form the subject of a separate chapter.

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* *Army Regulations on Ventilation.*—The Surgeon-General or Deputy-Surgeon-General or Sanitary Officer or Medical Officer of a Corps or Station, is directed by the Hospital Regulations to see that the ventilation of barracks, guard-rooms, day-rooms, schools, reading-rooms, cells, and hospitals is good, and that the number of men in any room does not exceed the regulation number.

The number of men placed in a barrack-room or hospital-ward is to depend on the cubic space.

| | | |
|---|---|---|
| In permanent barracks a man is allowed | 600 | cubic feet. |
| In wooden huts, | 400 | ,, |
| In hospital wards at home, | 1200 | ,, |
| ,, ,, in the tropics, | 1500 | ,, |
| In wooden hospitals at home, | 600 | ,, |

The number of men in each room is ordered to be painted on the door.

Before temporary hospitals are organised, the sanitary or other medical officer is to consider and report on the ventilation as well as other things.

The surgeon or medical officer in charge of a regiment is directed to visit "at frequent intervals" all barracks, quarters, hospitals, cells, married soldiers' quarters, to note their general sanitary condition, including ventilation. He is also to examine latrines, stables, &c.

On field service and on transport ships the same duties are enjoined.

The most constant attention is therefore ordered to be paid to this subject.

With the exception of ordering a certain cubic space, the Medical Regulations do not give any specific rules as to the rate of change of air, but the Report of the Barrack Commissioners (1861) orders that arrangements be made to supply at least 1200 cubic feet per head per hour, or, in other words, that the 600 cubic feet of air shall be changed twice in the hour.

In the Queen's Regulations for the Army, the ventilation of cells, barracks, and transport ships is also ordered.

The regulations thus require the medical officer to be able to report on the sufficiency or otherwise of ventilation; or, in other words, on the rate of movement, and on the purity of the air.

## SECTION I.

## QUANTITY OF AIR REQUIRED.

### 1. *Quantity required to remove the respiratory impurities caused by healthy persons.*

The impurities added to the air by respiration have been already enumerated (p. 105).

The carbonic acid which an adult man adds, to the extent of about $\frac{6}{10}$ths of a cubic foot in an hour, is not within certain limits an important impurity, but it is practically in a constant ratio* with the more important organic matter of respiration; and, as it is readily determined, it is taken as a convenient index to the amount of the other impurities.†

Taking the carbonic acid as the measure of the impurity of the air vitiated by respiration (and by respiration alone),‡ we have to ask, What is to be considered the standard of purity of air in dwelling-rooms? We cannot demand that the air of an inhabited room shall be absolutely as pure as the outside air; for nothing short of breathing in the open air can ensure perfect purity at every respiration.§ In every dwelling-room there will be some impurity of air.

The practical limit of purity will depend on the cost which men are willing to pay for it. If cost is disregarded, an immense volume of air can be supplied by mechanical contrivances, but there are comparatively few cases in which this could be allowed.

Without, however, attempting too much, it may be fairly assumed that the quantity of air supplied to every inhabited room should be great enough to remove all sensible impurity, so that a person coming from the external air should perceive no trace of odour, or difference between the room and the outside air in point of freshness. Taking the carbonic acid as the index of impurity, it appears, from experiments made by Dr de Chaumont and myself, that the organic impurity of the air is not perceptible to the senses until the carbonic acid (*i.e.*, the initial and the respiratory carbonic acid) rises to the ratio of ·6 per 1000 volumes, or ·0006 in each cubic foot. Occasionally air may seem pure to the senses when the carbonic acid is ·7 or even ·8 per 1000 volumes, but the usual rule seems to be that when it exceeds ·6, the air commences to become perceptibly impure. When the carbonic acid reaches ·9 or 1· per 1000 volumes, the air is what is called close and fusty; above this, it becomes disagreeable. In order to perceive the smell of the organic matter, the room should be entered from the fresh outside air, as after the observer has been a few minutes in the room the odour becomes imperceptible.

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* I say it is practically in a constant ratio, because it is so in perhaps 99 cases out of 100, though there may be exceptional cases when the organic matter may be in excess. I think, for adult men, the amount of ·6 cubic feet per hour is a very close approximation. The most perfect experiment yet made is by Pettenkofer, who in a man aged 28, and weighing 60 kilogrammes (=132 ℔ avds.), and taking little muscular exertion, found the carbonic acid in 24 hours amount to 911·5 grammes, or 461 litres at 0° cent. This corresponds to ·68 cubic foot per hour. The actual amounts were 0·78 in the day time, doing very little work; and 0·56 at night in a state of repose. This gives 0·00424 per ℔ of body-weight in repose, and 0·0059 in very gentle exertion. During hard work the same man evolved 1·52 per hour, or 0·015 per ℔ of body-weight. As we may, however, take the average of adult males (such as soldiers) at 145 to 150 ℔, the amount evolved in repose would be from 0·615 to 0·636 per hour. The assumed amount ·6, is therefore, for adult males, well within the actual amount observed in this case.

† One of the earliest observers to recognise the value of carbonic acid as an index of purity, appears to have been F. le Blanc, whose memoir, Récherches sur la Composition de l'Air Confiné (1842), is citedby General Morin. He appears to have had clearer notions as to the amount of air necessary than most of his contemporaries.

‡ This, of course, includes transpiration, or carbonic acid exhaled from the person in any way; but excludes all other sources, such as lights, fire, &c.

§ Thus the carbonic acid in the air being taken at ·04 per cent., and the carbonic acid of respiration being placed at ·6 cubic feet in an hour, a man placed in a room of 1000 cubic feet of air must receive no less than 1,000,000 cubic feet of outside air in an hour to reduce the carbonic acid to the standard (nearly ·0401 per cent.) of the fresh air.—*On Ventilation and Cubic Space.* By Dr de Chaumont, Assistant Professor of Hygiene, Army Medical School. Edinburgh Med. Jour. May 1867.

Pettenkofer has now adopted the limit of ·7 measures of $CO_2$, and Degen ·66 measures per 1000, as the amount when the organic matter simultaneously present becomes perceptible. I would propose, then, to adopt the amount of ·6 per 1000 volumes, or ·0006 per cubic foot, of total carbonic acid (initial and respiratory) as the limit of impurity. I admit that I am not able to show by direct evidence that impurity, indicated by ·7 or ·8, or even 1 volume of carbonic acid per 1000, and organic impurities in proportion, is injurious to health. We possess no means of testing the effects of such small quantities. Such a standard must be adopted, first, on the general evidence that large aerial impurities are decidedly hurtful, and that smaller amounts may be presumed to be so in proportion, although we cannot measure the action; and secondly, on the fact that we have an obvious and simple measure in the effect produced on the senses, which gives us a practical line of demarcation we could not otherwise obtain.

In a paper by Dr de Chaumont,* it is shown, from a large number of observations (473 analyses,) that the sense of smell carefully employed gives a very fair idea of the amount of impurity in an air-space. In those experiments the amount of carbonic acid in the external air was determined at the same time, so that the respiratory impurity was accurately known. Dividing the observations into groups the following results were obtained:—

| | 1. Fresh, or not differing sensibly from the outer air. | 2. Rather close. Organic matter becoming perceptible. | 3. Close. Organic matter disagreeable. | 4. Very close. Organic matter offensive and oppressive; limit of differentiation by the senses. |
|---|---|---|---|---|
| Mean $CO_2$ per 1000 vols. reduced to 0° cent. (=32° F.), due to respiratory impurity. | 0·1943 | 0·4132 | 0·6708 | 0·9054 |

*It will thus be seen that the smell of organic matter is, on an average, perceptible to the sense of smell when the coincident $CO_2$, due to respiratory impurity, reaches 0·1943 per 1000; and that when it exceeds 0·9054 the smell is no longer able to detect shades of difference.* Assuming the average ratio of $CO_2$ in external air to be 0·4 per 1000, the inferior limit will be 0·5943, or closely approaching 0·6 as above adopted. We may therefore take 0·2 per 1000 in round numbers as the maximum amount of respiratory impurity admissible in a properly ventilated air-space.

Adopting, then, this standard as the measure of the permissible maximum of impurity, the next point is the quantity of pure external air which should pass through the air of a room, vitiated by respiration, per head per hour, in order to keep the carbonic acid at this ratio. The following table gives the answer to this question, under different conditions of cubic space:—

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* On the Theory of Ventilation. Proceedings of the Royal Society No. 158, p. 187, 1875 and No. 171, 1876.

TABLE *to show the degree of Contamination of the Air (in terms of carbonic acid) by Respiration, and the amount of air necessary to dilute to a given standard of ·6 per 1000 volumes of air, of which ·4 is the carb: acid naturally existing, and ·2 is from respiration. In the table a deduction is made of the initial ·4 volumes of carbonic acid per* 1000, *for the sake of clearness.*

| Amount of cubic space (=breathing space) for one man in cubic feet. | Ratio per 1000 of carbonic acid from respiration at the end of one hour, if there has been no change of air. | Amount of air necessary to dilute to standard of ·2, or, including the initial carbonic acid, of ·6 per 1000 volumes, during the first hour. | Amount necessary to dilute to the given standard every hour after the first. |
|---|---|---|---|
| 100 | 6·00 | 2900 | 3000 |
| 200 | 3·00 | 2800 | 3000 |
| 300 | 2·00 | 2700 | 3000 |
| 400 | 1·50 | 2600 | 3000 |
| 500 | 1·20 | 2500 | 3000 |
| 600 | 1·00 | 2400 | 3000 |
| 700 | 0·85 | 2300 | 3000 |
| 800 | 0·75 | 2200 | 3000 |
| 900 | 0·66 | 2100 | 3000 |
| 1000 | 0·60 | 2000 | 3000 |

As already stated, for the sake of simplicity, the carbonic acid naturally in the air has been disregarded, but, of course, there would be actually in the air ·4 volumes per 1000 more from this source. Thus in the room of 100 cubic feet there would be at the end of an hour (·04 + ·6) ·64 volumes, or 6·4 per 1000, and in the room of 200 cubic feet there would be ·34 volumes per cent., or 3·4 per 1000.

The above table is calculated by the following formula of Dr de Chaumont:—*

Let R be the ratio of $CO_2$ naturally in the air (viz. ·0004 per cubic foot);

$r'$ be the additional ratio per cubic foot of air of vitiation by respiration of one male adult in an hour (the average being ·6 cubic foot of carbonic acid);

$r$ be the ratio per cubic foot of air to which it is desired $r'$ should be reduced;

$c$ be the capacity in cubic feet of the air space;

$d$ be the delivery of fresh air in cubic feet;

$v$ be the entire volume of the air, viz., $c + d$.

The formula is—

$$\frac{r' - R}{r - R} \times c = v \text{ and } v - c = d;$$

or $v$ may be eliminated thus:—

$$\frac{r' - r}{r - R} \times c = d;$$

or, in other words, the difference between the degree of vitiation and the admissible limit, divided by the excess of the admissible limit over the ratio in the outer air, gives a number, by which the capacity of the air-space must be multiplied, in order to find the amount of fresh air required to reduce the vitiation to the admissible limit.

In the table already given, as the standard of practicable purity is taken as ·2 per 1000 of $CO_2$ (= ·0002 per cubic foot) from respiration, and this is

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* Lancet, Sept, 1866, and Edin. Med. Journal, May 1867. These papers can be referred to for several useful formulæ. I would also refer to the Blue-Book of the Committee on the Cubic Space of Metropolitan Workhouses (1867), in which will be found several papers, especially one by Professor Donkin, in which this subject is mathematically treated.

$\frac{1}{30}$th of 6· (the ratio per 1000, that is, of vitiation from respiration in the room with 100 cubic feet), the multiplier is 30; in the room with 200 cubic feet ·2 is $\frac{1}{15}$th of 3· (the ratio of vitiation), and the multiplier is 15, and so on.

The answer may also be obtained by another formula of Dr de Chaumont's. Let $e$ be the assumed quantity of $CO_2$ evolved by one individual per hour; and $\rho$ be the amount of respiratory impurity per cubic foot; than $\frac{e}{\rho} = d$, the required delivery of air per hour in cubic feet. Thus if $e$ be taken at 0·6 of a cubic foot, and $\rho$ be the admissible limit of respiratory impurity, namely, 0·0002 per foot, then we have: $\frac{0{\cdot}6}{0{\cdot}0002} = 3000$ cubic feet of air per head per hour to keep the air in the required condition. Conversely the formula may be used to find how much air has been delivered and utilised during the period of occupation. Thus, in an experiment the amount of total $CO_2$ was found to be 1·1 per 1000, or 0·0011 per foot;—the amount in the open being 0·0004 per foot, we have the respiratory impurity $(\rho) = 0{\cdot}0011 - 0{\cdot}0004 = 0{\cdot}0007$; therefore we find: $\frac{0{\cdot}6}{0{\cdot}0007} = 857$ cubic feet of air per head per hour as the mean amount supplied and utilised during the period of occupation.

If the standard of practicable purity, viz., ·6 of carbonic acid per 1000 volumes (of which ·2 is derived from respiration) is considered too high, as involving too great a cost, and if ·7, ·8, or ·9 be taken, the amount of air required per head per hour will be 2000, 1500, and 1200 cubic feet respectively. If the emission of carbonic acid is taken, not at ·6 cubic foot per hour, but as something less, as in the case of women and children, a less amount of air would suffice, and can be calculated out at once from the formula.

In reference to a proposed standard, it is now earnestly to be wished that there should be a general agreement among medical men on the point; and I hope that the reasons already assigned will be considered sufficient to warrant the general adoption of ·6 per 1000 of carbonic acid, or rather, 0·2 per 1000 of respiratory impurity, as the standard of permissible maximum impurity.

The amount of fresh air thus determined by calculation is in accordance with that determined by actual experiment. I have measured the air passing out of barracks and hospital wards, and found that when 1200 or 1400 cubic feet per head per hour only were given, the carbonic acid reached ·7, ·8, or ·9 per 1000 volumes, and that more than 2000 cubic feet were necessary to keep the air pure to the senses. Dr de Chaumont's analyses* agree closely with this; so also the older experiments by Grassi, in Paris, at Mazas, and the latter observations of General Morin, as well as the observations and calculations of others, all fairly agree in this respect.

General Morin,† from analysis of all the observations made in Paris, and from experiments of his own, gives the following amounts:—

Amount of fresh air to be supplied per head per hour in temperate climates in the following circumstances:—

In barracks, = 30 cubic metres by day = 1059 cubic feet; 60 by night, = 2118 cubic feet. Workshops, = 60 cubic metres = 2118 cubic feet. Schools, = 30 cubic metres = 1059 cubic feet. Hospitals, = 80 cubic metres day and night = 2825 cubic feet (in epidemics, 160 cubic metres).*

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* Army Medical Department Reports, vols. v. vi. and vii.

† Rapport de la Commission sur le Chauffage et la Ventilation des Batimens du Palais de Justice. Paris, 1860. The older observers gave much smaller amounts, but I do not quote them.

Ranke, in his work on Physiology,† fixes the quantity at 60 cubic metres (2118 cubic feet) as the necessary minimum amount.

Roth and Lex‡ adopt the maximum of ·6 per 1000; but as they estimate the expired $CO_2$ as 20 litres,§ or ·706 cubic feet (Eng.) per hour, they give the hourly quantity of air as 100 cubic metres, or 3500 cubic feet.

In mines which are thought to be well ventilated, not less than 1400 cubic feet are given per head per hour, and if there is much fire-damp, as much as 6000 cubic feet have been supplied.‖ A horse requires 2450 cubic feet per hour at the least. Märcker has lately given the following amount from experiments:—For big cattle of 1000 ℔ weight, 30–40 cubic metres (= 1059–1412 cubic feet); for little cattle of the small weight, 40–50 cubic metres (= 1412–1765 cubic feet). These amounts seem very small, but Märcker's reasons for not giving more seem to be on account of the lowering of the temperature.

Although, in order to give precision to the subject, it is necessary to attempt to define the minimum quantity which is necessary, there is no doubt it is advantageous to have a larger amount. In the case of men in active work the amount of air must must necessarily be larger than in repose. Even assuming the erect instead of the recumbent position increases the amount of carbonic acid given off. As men in work appear to give off from 0·0060 to 0·0115 of a cubic foot of $CO_2$ per ℔ of body weight, according to the hardness of the work, it follows that, to keep the air to the adopted standard of purity, a man weighing 150 ℔s ought to have from 4500 to 8600 cubic feet of fresh air per hour, according to the amount of work he does. In short, wherever practicable, we should be contented with nothing less than an almost unlimited supply.

## 2. *On the Quantity of Air required for Lights, if the Air is to be kept Pure by Dilution.*

Air must be also supplied for lights if the products of combustion are allowed to pass into the room. Wolpert has calculated that, for every cubic foot of gas, 1800 cubic feet of air must be introduced to properly dilute the products of combustion; and this is not too much if we remember that a cubic foot of good coal gas produces about 2 cubic feet of carbonic acid, and that sulphuric acid and other substances may be also formed. A common gas burner will burn nearly 3 feet per hour, and will consume 10 or probably 12 cubic feet in an evening (4 hours), and therefore from 18,000 to 21,600 cubic feet of air must be introduced for this purpose alone in the 4 hours, unless the products of combustion are removed by a special channel. The power of illumination being equal, gas does not produce more carbonic acid than candles (Odling), but usually so much more gas is burnt that the air is much more deteriorated; there is also greater heat and more watery vapour. The

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[*] These amounts are somewhat modified in his Manual Pratique du Chauffage and de la Ventilation, 1874. They are, however, all too low for good ventilation.

[†] Grundzüge der Phys., 1868, p. 376.

[‡] *Loc. cit.* p. 221.

[§] This amount is also adopted by General Morin.

[‖] It has been stated, from extensive observations, that, in mines, if it is wished to keep up he greatest energies of the men, no less than 100 cubic feet per man per minute (= 6000 per hour) must be given; if the quantity is reduced to one-third, or even one-half, there is a serious diminution in the amount of work done by the men. This amount includes, of course, all he air wanted in the mine for horses, lights, &c.—*Proceedings of the Civil Engineers*, vol. xii. pp. 298 and 308.

products should never be allowed to escape into the air of the room. Weaver has shown how important a source of impurity this is; and the bad effects of breathing the products of gas combustion are well known.

A ℔ of oil demands, for complete combustion, 138 cubic feet of air; and to keep the air perfectly pure, nearly as much air must be introduced for 1 ℔ of oil as for 10 feet of gas. In mines, 60 cubic feet per hour are allowed for each light; the lights generally are dim, and the amount of combustion is slight; but this seems an extremely small amount.

If gas is not burnt in a room, or in a very small amount, or if only candles or oil lamps are used, it is seldom necessary to take them into account in estimating the amount of air.

### 3. *On the Quantity required for the Respiration and Dilution of the Emanations of Sick Men.*

With regard to sick men, it is impossible to say what quantity should be given. In some diseases, so much organic substance is thrown off, that scarcely any ventilation is sufficient to remove the odour. At the Hospital Beaujon in Paris, it was shown, as long ago as 1847, that 60 cubic metres (= 2118 cubic feet) per head per hour did not remove all odour from the surgical wards after dressings. Grassi* mentions that a perceptible odour diffused from a case of cancerous ulcer in a ward in the Hôpital Necker at Paris, although the ventilation at the time was 3600 cubic feet per head per hour; but bad odour will perceptibly taint an hospital ward with a greater allowance of air even than this. Dr Sankey found the wards in the London Fever Hospital to be not free from odour when 3720 cubic feet per head per hour were passing in. In some of the London Hospitals Dr de Chaumont found that there was still a close smell when 5000 cubic feet and even more were supplied, but the distribution was not perfect. Even when 3600 feet were supplied and utilised (as calculated from the $CO_2$) the ward was not free from smell. In his paper on the "Theory of Ventilation" (Proceedings of the Royal Society *loc. cit.*), he showed that whilst the smell of organic matter was still imperceptible in barracks, among healthy men, when the air contained 0·208 of $CO_2$ per 1000, it was quite distinct in hospitals (among ordinary cases) when the $CO_2$ amounted to 0·166; so that if 3000 cubic feet per hour be put as a minimum in health, this ought to be increased by one-third, giving 4000 as a minimum in sickness even of an ordinary character,—to be increased, of course, without limit in cases of a serious nature. In the new Hôtel Dieu at Paris, it is intended to give at least 100 cubic metres (3500 cubic feet) per head per hour; but this amount is not sufficient. Dr Sutherland believes that at least 4500 cubic feet per head per hour must be allowed when there are many bad cases, and especially surgical cases with open wounds; and during epidemics, or when hospital gangrene, pyæmia, or erysipelas are spreading, 6000 cubic feet at least must be given; or, in other words, the supply must be almost unlimited. The best surgeons now consider an almost complete exposure of pyæmic patients to the open air the best treatment; and it is well known that in typhus fever and (to a less extent) in typhoid, and also in small-pox and plague, this complete exposure of patients to air is the first important mode of treatment, before even diet and medicines. Even temperature must be sacrificed to a considerable extent, in order to obtain fresh air, if a choice requires to be made between the two.

*Humidity.*—The condition of the air as regards humidity is a matter of some importance, but has not hitherto been much considered. In Dr de Chaumont's experiments the mean humidity, in rooms having less than 0·2 per 1000 of respiratory impurity (reckoned as $CO_2$), was 73 per cent., at a temperature of 63° Fahr. This might be taken, provisionally, as a standard.*

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* Etude Comparative des Deux Systèmes de Chauffage et de Ventilation, &c. Par C. Grassi, 1856, p. 12.

## SECTION II.

## THE MODE IN WHICH THE NECESSARY QUANTITY OF FRESH AIR CAN BE SUPPLIED.

This is an engineering problem, and there can be no doubt that in time to come it will be as carefully considered by engineers as the supply of water, or the removal of the solid and fluid excreta. Ventilation is, in fact, the problem of the removal of the gasiform excreta of the lungs and skin.

### SUB-SECTION I.—PRELIMINARY CONSIDERATIONS.

1. *Cubic Space.*†—A certain amount of fresh air has to pass through a given air space in a fixed time to order to maintain a certain degree of purity; the amount has been fixed (page 143) at 3000 cubic feet for each adult healthy male in an hour; before considering the appliances for moving this air, we must consider what should be the minimum size of the air space for each healthy male adult through which the fresh air has to pass.

This will entirely depend on the rate at which air can be taken through the space without the movement being perceptible or injurious. The size of the space is chiefly of consequence, as it affects this condition. The larger the air space the less is the necessity for the frequent renewal of air, and the less the chances of draught. Thus a space of 100 cubic feet must have its air changed thirty times in an hour, if 3000 cubic feet of air are to be given, while a space of 1000 cubic feet need only have it changed three times in an hour for an equal ventilation.

When the most perfect mechanical means are employed, the air of even a small air space can be changed sufficiently often without draught. Thus, in Pettenkofer's experimental room at Munich, the air space is 424 cubic feet, and 2640 cubic feet can be drawn through by a steam engine in an hour without perceptible movement; in other words, the change is six times per hour nearly. With the best mechanical contrivances, and with disregard of cost, we are therefore certain that a cubic space of 424 feet would be sufficient, and there is every probability that engineers could ventilate even a smaller space without perceptible movement.

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* From the state of the air as regards humidity, information may sometimes be obtained which might take the place of the $CO_2$ determination, in the absence of means for carrying out the latter. For instance, at St Mary's Hospital the air of the wards was found to have 78 per cent. of humidity, or 5·8 per cubic foot; to reduce it to 73 per cent., or 5·5 grains per cubic foot, while the external air contained 5·2, we should have $\frac{5·8 - 5·5}{5·5 - 5·2} = \frac{0·3}{0·3} = 1$, or we should require to add to the existing delivery of air, at least as much more per hour as would equal the total cubic space. In the case referred to this was about 2256 cubic feet. The actual supply was 2080, total 4336 per head, or about the quantity demanded for proper hospital ventilation.

† For the rules on the measurement of cubic space, see the chapter on the Examination of Air. In the metropolitan lodging-houses, 30 superficial and 240 cubic feet are allowed; in the section-houses of the metropolitan police 50 feet superficial and 450 cubic feet are given. The Poor-law Board allows 300 cubic feet for every healthy person in dormitories, and from 850 cubic feet and upwards, according to circumstances, as far as 1200 cubic feet for every sick person. In Dublin an allowance of 300 cubic feet is required in the registered lodging-houses. (From an excellent pamphlet, entitled Essentials of a Healthy Dwelling, p. 18.) In the Prussian army the allowance is 495 cubic feet (Prussian measurement, which is nearly the same as English), the superficial space being 42–45 square feet; in the old Hanoverian army the cubic space was 700 to 800 cubic feet (Prussian). The London School Board have given, in a general schoolroom, 10 square feet per scholar, and in graded schools 9 square feet; the height was ordered to be 13 feet—making 130 and 117 cubic feet respectively. This seems very small.

But if the mechanical contrivances are of an inferior kind, and particularly if natural ventilation is used, the difficulties of ventilating a small space are considerable, and are caused not so much by the rate of movement of the greater part of the air in the room, as by the rate at the openings where the fresh air comes in very quickly, and causes currents in the room. Suppose, for example, a space of 500 cubic feet with a man in it, who has to be supplied with 3000 cubic feet in an hour; if the inlet opening be 12 square inches, the rate of movement through it would be 10 feet per second, or nearly 7 miles per hour; if 24 square inches, it would be 5 feet, or about 3·4 miles per hour. In either case, in such a small room, the air could not be properly distributed before reaching the person, and a draught would be felt. If instead of 500 cubic feet 1000 were given, the problem is easier, for the small current of fresh air mixing with the larger volume of air in the room is more easily broken up, and the man being further from the opening the movement is less felt. The question, in fact, turns in great measure on the power of introducing the air without draught.

If the change of air is carried on by what is termed natural ventilation, and under the ordinary conditions of this climate, a change of air six times per hour, as in Pettenkofer's room, could not be attempted. Even five times per hour would be too much, at least in barracks with 600 cubic feet per head, the rooms are cold and draughty, when anything approaching to 3000 cubic feet per head per hour are passing through; that is a change of five times per hour for each 600 cubic feet of air space. A change equal to four or three times per hour is, I believe, generally all that can be borne under the conditions of warming in this country, and if this be correct, from 750 to 1000 cubic feet should be the minimum allowance of the initial air space.*

With good warming and an equable movement which, however, is not always easy to get, there might be larger inlets, and therefore more easy distribution and a smaller air space to begin with. If the inlets are 48 square inches, the rate through them to supply a space of 500 cubic feet with 3000 cubic feet per hour, would be only 2½ feet per second; and if, as should be the case in artificial ventilation, the inlet is 72 or 80 square inches in size, the rate would only be a little over 1½ foot per second, which would be imperceptible even at the orifice. But there is an argument against a small cubic space even with good mechanical ventilation, viz., that if anything arrests the mechanism for a time, the ratio of impurity from respiration increases much faster in a small than in a large space.†

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* It will, of course, be perceived that the whole argument turns on the assumption of the correctness of the standard of practicable purity, viz., ·6 volume sof carbonic acid per 1000. If a less pure standard is fixed, the amount of fresh air per hour would of course be less; but I hope the purer standard will be adopted.

† Experimental data on many of these points are still wanting. In prisons, with cells for separate confinement and artificial ventilation, the amount of space is seldom under 750 to 800 cubic feet, and practically this is found to be too small.

In Pentonville Prison, on Jebb's system, the air was hardly ever changed three times in the hour, during my experiments, although the cells are nearly 800 cubic feet in capacity. The mean supply of air per hour was about 1050 cubic feet. In Gosport military prison, also on Jebb's principle (but not perfectly carried out), the mean supply was about 800 cubic feet, but the cells are only about 600 in capacity. In Aldershot military prison (not on Jebb's principle) with cells about 600 cubic feet in size, the mean supply was under 500. And in Chatham convict prison, where the cells are only 200, the mean supply was about 490. Wilson (Handbook of Hygiene) appears to have found the air changed in the large cells at Portsmouth convict prison about 3 times in the hour, and in the small about 4 times; this, however, is certainly not the rule. (F. de C.)

The warmth of the moving air influences the sensation of the persons exposed to it. At a temperature of 55° or 60°, a rate of 1½ feet per second (= 1 mile per hour nearly) is not perceived; a rate of 2 and 2½ feet per second (1·4 and 1·7 miles per hour) is imperceptible to some persons; 3 feet per second (2 miles per hour nearly) is perceptible to most; a rate of 3½ feet is perceived by all persons; any greater speed than this will give the sensation of draught, especially if the entering air be of a different temperature, or moist. If the air be about 70° Fahr., a rather greater velocity is not perceived, while if it be still higher (80° to 90° Fahr.), the movement becomes again more perceptible, and this is also the case if the temperature be below 40° Fahr. If the air could be warmed to a certain point in a cold climate, or if the climate be warm, there may be a much more rapid current, and consequently a smaller cubic space might be given. The subject of ventilation is in cold climates connected inseparably with that of warming, for it is impossible to have efficient ventilation in cold weather without warming the air. (See chapter on WARMING.)

The above remarks apply to adult males; for women and children it might be considered that the amount of fresh air and of cubic space should be less, as they vitiate the air less than men. But as the difference between women and men is not great, and as children, in proportion to their size, undergo a more rapid tissue change than adults, it would be the safest course to have the same rule for all individuals of whatever age, except the very youngest and oldest, who require special conditions of warming. Some persons, however, class two children as one adult; but if this be adopted, the rule should, at any rate, be restricted to children under five years old.*

The amount of cubic space thus assigned for healthy persons is far more than most people are able to have; in the crowded rooms of the artizan class, the average entire space would probably be more often 200 or 250 cubic feet per head than 800. The expense of the larger rooms would, it may be feared, be fatal to the chance of such an ideal standard being generally carried out; but, after all, the question is, not what is likely to be done, but what ought to be done; and it is an encouraging fact that in most things in this world, when a right course is recognised, it is somehow or other eventually carried out.

So, in the case of soldiers, the amount of authorised regulation space (600 cubic feet), is below the standard now given, but still the space is as much as can be demanded at present. It has been found very difficult, without incurring greater expense than the country would bear, to give every man even the 600 cubic feet, and as soldiers are healthy men, and can bear rapid movement of air, and as some of the entering air is warmed by the barrack grate, the 600 cubic feet may possibly suffice.

For sick persons the cubic space should be more than for healthy persons. We are to remember that there are other impurities besides those arising from respiration and transpiration, and that immediate dilution and as speedy removal as can be managed are essential.

Very much the same considerations apply to sick as to healthy men, except that the allowance of air in all cases of acute diseases must be greater; and, therefore, especially if natural ventilation be employed, the cubic space has to be enlarged also, to insure good distribution without draught, for surface chilling must be carefully avoided.

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* If any difference is made, children ought to be considered as evolving not less, than 0·45 of a cubic foot of $CO_2$ per hour; the amount 0·6 ought to be retained for women, and 0·7 ought to be allowed for men. In this way the minimum hourly supply in health in repose ought to be:

For children, . . 2250; for women 3000; for men 3500.
In ordinary sickness, 3400; „ 4000; „ 5250.

Admitting that on an average 4000 cubic feet of fresh air should be supplied, in hospitals, per patient per hour, and if the change of air is to be four or three times per hour, as the best rate of movement, the cubic space must be 1000 or 1300 cubic feet respectively. A consideration of another kind may aid in determining the question as regards sick men. In hospitals a certain amount of floor space is indispensably necessary; first, for the lateral separation of patients; secondly, for convenience of attendance. For the first object the greater floor space the better; and in respect of the second, Dr Acland has clearly shown that the *minimum* floor space for convenient nursing should be 72 square feet per bed.[*] In a ward of 12 feet in height this would give 864 cubic feet.

Considering, however, the immense benefit to patients of pure air, and the practical experience of hospital physicians, it is very desirable not to fix the floor and cubic space of hospital wards intended for acute and surgical diseases, and for cases with copious discharges, at the minimum of what may suffice. The desire of most hospital physicians and surgeons is to obtain for their patients, if they can, a floor space of 100 to 120 square feet, and a cubic space of 1500 to 2000 cubic feet, and I believe that this is true wisdom.

A notion prevails among many people, that cubic space may take the place of change of air,—so that if a larger cubic space be given, a certain amount of change of air may be dispensed with, or less fresh air be required. This is quite erroneous: even the largest space can only provide sufficient air for a limited time, after which the same amount of fresh air must be supplied hourly, whether the space be large or small. This is shown by the table on page 143. Even in a space of 10,000 cubic feet per head the limit of admissible impurity would be reached in a little over 3 hours, after which the same hourly supply of 3000 feet would be as necessary as in a space of 100 cubic feet.[†]

The amount of ventilation for animals has not been experimentally determined to my knowledge. A horse is said to require at least 2466 cubic feet of fresh air per hour, but he probably requires more, and the analysis of the air of stables shows that the air has frequently been very impure.[‡] At present, the Army Regulations allow, in new stables, each horse 1605 cubic feet, and 100 square feet of floor space;[§] and the means of ventilation, as will be presently noticed, are ample. In the new Army Horse Infirmaries, the superficial area is to be 127 square feet, and the cubic space 1900 feet per horse.

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[*] See report of the Committee appointed to inquire into the cubic space of Metropolitan Workhouses, 1867, p. 12.

[†] For further remarks on this point see my Lectures on State Medicine; also Hygiène in the Sanitary Record, 1874–5. In a pamphlet by General Morin, Note sur l'espace cubique, &c., a table is given that might be misleading, without explanation. It really shows the amount of air necessary to dilute a certain amount of impurity evolved in a certain cubic space, and is similar to the table given on page 143 of this work. For continuous ventilation the necessary supply in any ordinary space after the first hour, is a constant quantity. (F. de C.)

[‡] If there is a constant relation between weight and the evolution of $CO_2$ (as seems likely), then a horse, weighing 500 ℔ would evolve per hour about 2 cubic feet of $CO_2$ which would require 10,000 cubic feet of air to reduce to the standard adopted for men. The supply above named (2466) would reduce the impurity to from 0·8 to 1·0 per 1000 according to the size of the animal; adding to this 0·4 for the incoming air, we have 1·2 to 1·4 as the probable condition of the air of the stable. Märcker fixes the standard at 2·5 to 3.0 per 1000, which would argue a delivery of air of only about 800 to 1000 per hour, certainly too small.

[§] Report of the Barrack and Hospital Improvement Commission on the Ventilation of Cavalry Stables, 1863, p. 10.

In the stables of cattle there is often excessive over-crowding, and it is well-known that there is a vast amount of disease among them, which, however, is seldom allowed to go far, as they are sent to the butcher. Dr Ballard, who paid great attention to the cattle plague in Islington, recommended that at least 1000 cubic feet should be allowed per animal.

2. *Source of the air supplied.*—In order that the object of the ventilation shall not be defeated, it is necessary that the air entering a room shall be pure. The air must be the pure external air, and not be derived from places where it has stagnated and taken up impurities; if it is drawn along passages or tubes, and through louvres or basements, these should be capable of inspection and cleansing. All air-shafts should, if possible, be short and easily cleaned. This is an important rule, and should lead to the rejection of all plans in which the air-shafts are long and incapable of being cleaned. I have seen several instances of air being distributed by costly appliances, and yet being drawn from an impure source, or allowed to be contaminated on its passage. Instead of perforated bricks, there should be sliding panels, or hinged flaps, so that the tube may be easily reached.

3. *Warming or cooling of the air.*—The air may require to be warmed to 60° or 65° Fahr., or cooled according to the season or locality. The warming in cold and temperate climates is a matter of necessity, as, if discomfort is caused by cold draughts, ventilation openings are certain to be closed.

4. *Distribution.*—The distribution in the rooms should be perfect, that is, there should be uniform diffusion of the fresh air through the rooms. The best way of ascertaining this is to compare the amount of air utilised, as calculated from the observed $CO_2$, with the actual movement of air, as measured with the air-meter. If the distribution is good the two quantities ought not to differ materially. Much difficulty is found in properly managing uniform diffusion, and it requires careful arrangement of the various openings. The distributing plans should, if possible, prevent the chance of breathed air being rebreathed, especially in hospitals. As the ascent of respired air is rapid, on account not only of its temperature, but from the force with which it is propelled upwards, for patients in bed, the point of discharge should be above.

During the last few years it has been argued that it is better that the foul air should pass off below the level of the person, so that the products of respiration may be immediately drawn down below the mouth, and be replaced by descending pure air. But the resistance to be overcome in drawing down the hot air of respiration is so great that there is a considerable waste of power, and the obstacle to the discharge is sometimes sufficient, if the extracting force be at all lessened, to reverse the movement, and the fresh air forces its way in through the pipes intended for discharge. This plan, in fact, must be considered a mistake. The true principle is that stated long ago by D'Arcet. In the case of vapours or gases the proper place of discharge is above; but heavy powders, arising in certain arts or trades, and which from their weight rapidly fall, are best drawn out from below.

## SUB-SECTION II.—MEANS BY WHICH AIR IS SET IN MOTION.

These are :—1*st*, the forces continually acting in nature, and which produce what has been termed natural ventilation. 2*d*, The forces set in action by man, and which produce the so-called artificial ventilation.

The division is convenient, but not strictly logical, as the forces which act in natural do so also in artificial ventilation to a certain extent.

## NATURAL VENTILATION—GENERAL STATEMENTS.

Three forces act in natural ventilation, viz., diffusion, winds, and the difference in weight of masses of air of unequal temperature.

### 1. DIFFUSION.

As every gas diffuses at a certain rate, viz., inversely as the square root of its density, there is a constant escape of any foreign gas into the atmosphere at large. From every room that is not air-tight Pettenkofer and Roscoe have shown that diffusion occurs through brick and stone, and Pettenkofer believes that one of the evils of a newly built and damp house is that diffusion cannot occur through its walls. But the ordinary plastered and papered walls reduce diffusion to a most insignificant amount. Through chinks and openings produced by imperfect carpentry the air diffuses fast, and Roscoe found that when he evolved carbonic acid in a room the amount had decreased one-half from that cause in 90 minutes.

The amount of purification produced by diffusion under ordinary circumstances is shown by observation to be insufficient, and, in addition, organic substances, which are not gaseous, but molecular, are not affected by it. As a general ventilating power, it is therefore inadequate.

### 2. THE ACTION OF THE WINDS.

The wind acts as a powerful ventilating agent, and in various ways. If it can pass freely through a room, with open doors and windows, the effect it produces is immense. For example, air moving only at the rate of 2 miles an hour (which is almost imperceptible), and allowed to pass freely through a space 20 feet wide, will change the air of the space 528 times in one hour. No such powerful action as this can be obtained in any other way.

The wind will pass through walls of wood (single-cased), and even of porous bricks or stone; and perhaps this will account for the fact that such houses, though cold, are healthy habitations. By covering a brick with wax, or inclosing a portion of a brick wall in an air-tight box, Pettenkofer has shown that the force of the breath will drive air through the brick, and will blow out a candle on the other side if the current of air be collected in a small channel. The force required to drive the air through is, however, really considerable, as the air in the brick must be brought into a state of tension.

Märcker* has given the following as the amount of air passing in one hour through a square metre of wall space, when the difference of temperature is 1° C.:—Sandstone, 1·69; limestone, 2·32; brick, 2·83; tufaceous limestone, 3·64; and loamy brick, 5·12 cubic metres of air. The little porosity of sandstone depends on the amount of moisture it holds. The moisture, in fact, greatly influences the transit. Plaster, however, appears to arrest wind, if it be true, as stated, that in the interior of some thick walls, after many years, lime has been found still caustic; and Märcker also notices the obstructive effects of mortar.

There are two objections to winds as ventilating agents by perflation.

1. The air may be stagnant. In this country, and, indeed, in most countries, complete quiescence of the air for more than a few hours is scarcely known. Air is called "still" when it is really moving 1 or 1½ mile an hour. The average annual movement of the air in this country is from 6 to 12 miles per hour; but it varies, of course, greatly from day to day, and in different

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* Untersuch. über nat. et künstliche Ventilation. Göttingen, 1871. The ventilation of cattle stalls and stables is well discussed in this book. The standard of $CO_2$ is fixed at 2·5 to 3 per 1000 volumes of air.

But the wind acts in another way. *A moving body of air sets in motion* all air in its vicinity. It drives air before it, and, *at the same time, causes* a partial vacuum on either side of its own path, *towards which all the air in* the vicinity flows at angles more or less approaching right angles. In this way, a small current moving at a high velocity will set in motion a large body of air.

The wind, therefore, blowing over the tops of chimneys, causes a current at right angles to itself up the chimney, and the unequal draught in furnaces is owing, in part, to the variation in the velocity of the wind. Advantage, therefore, can be taken of this aspirating power of the wind to cause a movement of air up a tube. The wind, however, may impede ventilation by obstructing the exit of air from any particular opening, or by blowing down a chimney or tube. This is, in fact, one reason of the failure of so many systems of ventilation; they may work well in a still atmosphere, but the immense resistance of the wind has not been taken into account. At 3 miles an hour, the pressure of the wind is ¾ of an ounce on each square foot; it is 1 ounce at 3½ miles; 2 ounces at 5 miles; 4 ounces at 7 miles; ½℔ at 10 miles; and 1℔ at 14 miles. At Netley the average pressure is a little over ½℔ per square foot.

In some systems of ventilation the perflating power of the wind has been used as the chief motive agent. In Egypt the wind is allowed to blow in at the top of the house through large funnels. This plan has been in use from time immemorial. This was the case in Mr Sylvester's plan, which was used at Derby and Leicester forty or fifty years ago. A large cowl, turning towards the wind, was placed in a covenient spot near the building to be ventilated—a little above the ground if in the country, or at some height if in a town. The wind blowing down the cowl passed through an under-ground channel to the basement of the house, and entered a chamber in which was a so-called cockle-stove, or calorifere of metal plates, or water or steam pipes, by which the air was warmed. It then ascended through tubes into the rooms above, and passed out by a tube or tubes in the roof, which were covered by cowls turning from the wind. So that the aspiratory power of the air was also used. This plan is extremely economical, but the movement of the air is unequal, and it is difficult to regulate it. It has been proposed to place a fan in the tunnel to move the air in periods of calm, and the plan then becomes identical in principle, and almost in detail, with the method of Van Hecke.

Mr Ritchie* has employed a similar plan in the ventilation of a dwelling-house. The air is warmed in winter to about 70° Fahr.; every room has a longitudinal opening over each door, concealed by the architrave, and regulated by valves, and through this the warm air from the staircase enters the rooms, and then passes up the chimney, and up outlet air-flues placed in the walls, commencing at the ceiling, and ending at the wall-heads under the roof.

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* Treatise on Ventilation, by Robert Ritchie, C.E., 1862, p. 89.

Dr Arnott ventilated the Field Lane Ragged School on this principle with excellent effect, as is shown by the annexed cut. In this case, as in all others, the movement is also in part carried on by the third cause of motion in air, viz., the effect of unequal density of masses of air.

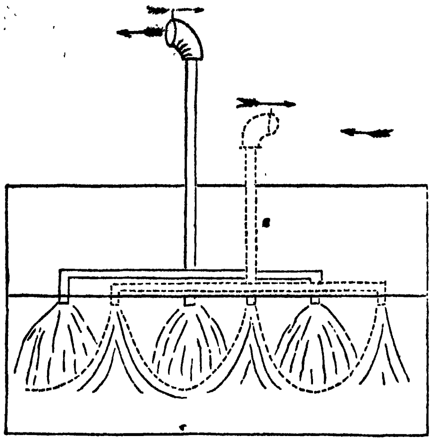

Fig. 11.

In the ventilation of ships, the wind is constantly used; and by wind-sails and tubes with cowls turning towards the wind, air is driven between decks and into the hold.

In using the wind in this way, the difficulty is to distribute the air so that it shall not cause draughts. This is best done by bending the tubes at right angles two or three times, so as to lessen the velocity, by enlarging the channel towards the opening in the interior of the vessel, and by placing valves to partially close the tubes, if necessary, and by screens of wire-gauze. *

In all cases in which the air of a room, as in a basement story, or in the hold of a ship perhaps, is likely to be *colder* than the external air, and when artificial means of ventilation cannot be employed, the wind should be taken advantage of as motive agent.

The aspiratory power of the wind can be secured by covering air-shafts with movable cowls turning from the wind, and special forms of covering hereafter described, which aid up currents and prevent down draughts.

### 3. MOVEMENTS PRODUCED BY UNEQUAL WEIGHTS OF AIR.

The wind itself is caused by this power; but it is necessary, in discussing ventilation, to look upon this as if it were an independent force. If the air in a room be heated by fire, or the presence of men or animals, or be made moister, it endeavours to expand; and if there be any means for it to escape, a portion of it will do so, and that which remains will be lighter than an equal bulk of the colder air outside. The outer air will then rush into the room by every orifice, until the equality of weight outside and inside is re-established. But as the fresh air which comes in is in its turn heated, the movement is kept up in a constant stream, cold air entering by one set of orifices, and hot air escaping by another.

We have now to inquire how the rate of this constant stream of air may be calculated.† The mode most generally used is based on two well-known laws: first, that the velocity in feet per second of falling bodies is equal to (nearly) 8 times the square root of the height through which they have fallen;

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* As the use of perforated zinc plates and of wire-gauze is very common in ventilation, it is necessary to bear in mind that these screens very soon get clogged with dirt. In all cases they should be so arranged as to be easily inspected and cleaned; and it should be a matter of routine duty to see that they are constantly kept clean. It should also be understood that the delay by friction through the fine wire-gauze is exceedingly great. I believe it is better to avoid their use as much as possible.

† Many of these points are given in Hood's Treatise on Warming and Ventilation, and in Wolpert (Principien der Vent. und Luftheizung), and are also discussed in Péclet (Traité de la Chaleur, 3d edit.), and by General Morin (Études sur la Ventilation, Paris, 1863, t. ii.), to which reference is made for those who wish to enter into the mathematical part of the inquiry.

and, second, that fluids pass through an orifice in a partition with a velocity equal to that which a body would attain in falling through a height equal to the difference in depth of the fluid on the two sides of the partition.* The pressure of air upon any surface may be represented by the weight of a column of air of uniform density of a certain height. Thus the pressure of the atmosphere at the surface of the earth is nearly 15℔ on the square inch, and this would be the weight of a column of air of about 5 miles in height. Air, therefore, rushes into a vacuum with a velocity equal to that which a heavy body would acquire in falling from a height of 5 miles, viz., 1304 feet per second. But if, instead of rushing into a vacuum, it rush into a chamber in which the air has less pressure than outside, its velocity will be that due to a height which represents the difference of pressure outside and inside. In ordinary cases this difference of pressure cannot be obtained by direct observation, but must be inferred from the difference of temperature of the outer and inner air. Air is dilated one part in 491 of its volume for every degree of Fahrenheit that its temperature is raised, consequently the difference of pressure outside and inside will be as follows:—

The height from the aperture at which air enters to that from which it escapes, multiplied by the difference of temperature between outside and inside, and divided by 491.

If the height be 20 feet, and the difference of temperature 15 degrees, we have the height to produce velocity of inflowing current $= \frac{20 \times 15}{491} = 0{\cdot}61$ of a foot, and the velocity $= 8\sqrt{{\cdot}61} = 8 \times {\cdot}781 = 6{\cdot}248$. This, however, is the theoretical velocity. In practice an allowance must be made for friction of $\frac{1}{4}$, $\frac{1}{3}$, or even $\frac{1}{2}$, according to circumstances. The diminution of velocity from friction is in proportion to the length of the tube, and is inversely as the diameter. Right angles greatly increase the friction.† The friction increases also as the square of the velocity. The deduction of $\frac{1}{4}$th would leave 4·686 linear feet per second as the actual velocity. If this be multiplied by the area of the opening, in feet, or decimals of a foot,‡ the amount of air is expressed in cubic feet per second, and multiplying by 60 will give the amount per minute.

A table is given at page 178, in which this calculation has been made for all probable temperatures and heights; but it must be remembered that the movement is greatly influenced by the wind.

This cause of movement is, of course, constantly acting when the temperature of the air changes. It will alone suffice to ventilate all rooms in which the air is hotter than the external air, but will not answer when the air to be changed is equal in temperature to, or colder than, the external air.

As its action is equable, imperceptible, and continuous, it is the most useful agency in natural ventilation in cold climates, in inhabited and warm rooms; and in all habitations arrangements should be made to allow it to act. As the action increases with the difference of temperature, it is most powerful in winter, when rooms are artificially warmed, and is least so, or is quite arrested in summer, or in hot climates, when the internal and external temperatures are identical.

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* This is frequently called the Rule of Montgolfier. The formula is $v = \sqrt{2gH}$; $g$ being the acceleration of velocity in each second, of time, viz., 32·18 feet, and H the height of the descent.

† The friction caused by angles is probably nearly in the proportion of $\frac{1}{1+\sin.^2\theta}$, where $\theta$ is the angle in the tube; by this formula right angles would cause a loss of one-half the velocity.

‡ It will be found always easier to take the area in decimals of a foot instead of inches; but if it be taken in inches, multiply the linear discharge by the number of square inches, and divide by 144.

### 4. PRACTICAL APPLICATION OF THE GENERAL STATEMENTS OF NATURAL VENTILATION.*

1. No particular arrangements are necessary to allow diffusion to act, except that there shall be communication between two atmospheres.

2. To obtain the perflation of the wind, windows should be placed, in all cases where it can be managed, at opposite sides of a room. The windows should open at the top, and in case the wind has a high velocity, means should be taken to distribute it. This can be done by sloping the window inwards when it opens, or a board may be placed obliquely upwards from the top sash of the window, when it opens in the usual way; then the air striking against the board is thrown up towards the ceiling. Or, wire-gauze may cover the space left when the window is open. The velocity of the wind is checked by the gauze, and the current is minutely divided.

Various plans have been proposed by different persons. The panes of glass may be made double, spaces being left at the *bottom* of the outside pane, and at the *top* of the inner one, so that the wind is obliged to pass up between the two panes before it enters the room. Or, the lower sash being raised, and a piece of wood placed below it, the air is allowed to pass through the space left between the upper and lower sashes. Or, glass louvres, which can be more or less closed, are placed in one of the panes of the window; or a number of holes are obliquely bored through the panes, through which the air may pass up towards the ceiling before it intermixes with the air of the room. In Lockhead's ventilator there is a frame over the glass louvre, with a regulator in the centre. In Cooper's ventilator a movable plate of glass can be brought by a movable handle over the opening.

Stallard has proposed to ventilate workshops and factories by having a double ceiling; the lower ceiling is to be made of zinc or oiled paper, perforated with very numerous small holes; and the space between the two ceilings is to be freely open to the air on all sides; thus there would be almost open-air breathing, as the communication with the external air would be constant and at all parts of the room.

Mr Potts proposes a double cornice, perforated through two sets of holes; the upper holes are connected by means of the upper tube of the cornice with the chimney, the lower with the outside air; the fresh air is supposed to enter the room, flow down the walls, and be generally diffused, while the vitiated air rises to the top, and passes off through the upper holes. It is believed in this way that continual movement and good distribution are secured. I have not seen the results of any systematic inquiry, but the plan has been well spoken of by some engineers.

Besides windows, special openings may be provided for the wind to blow through, as in the plans already referred to of Mr Sylvester and Dr Arnott.

In all warm climates, where no chill can be produced by wind, it is a good plan to make the walls entirely pervious. Nothing can be better than the ventilation of the bamboo matted houses in Burmah. The wind blows through them, but is so broken up into currents that it is not in the least unpleasant. Even in colder parts of India, the upper parts of the walls might be made thus pervious, provision being made to cover them, if necessary, in the cold season.

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* A very good account of the various plans in natural ventilation will be found in Mr Edward's work, "On the Ventilation of Dwelling-houses," 1868, in which figures of the plans are given.

To obtain the full effect of the aspirating power of the wind, chimneys or ventilating tubes should be fitted with cowls turning away from the wind. The cowl should be large, and should expand greatly towards the end, so as to make the calibre of the opening several times greater than that of the tube (fig. 13). Most cowls on chimneys are too small. The upper rim should also project a little, so as to lessen the chance of rain getting in.

Another form of covering is represented in fig. 12, and is also drawn in section (fig. 14). Whichever way the wind blows it almost always causes an up-draught. A little rain, however, may possibly penetrate, but otherwise it is as good as the cowl. Dr Macdonald's twin-fan ventilator may be used also (see fig. 21, page 164).

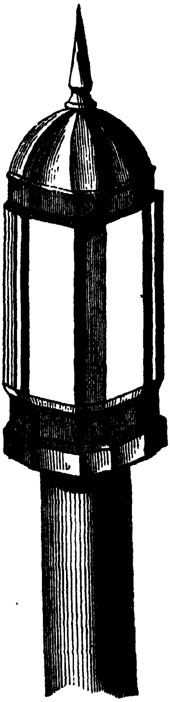

Fig. 12.

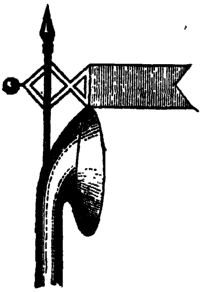

Fig. 13.

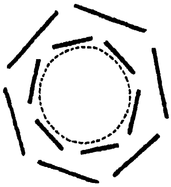

Fig. 14.
Section of Fig. 12.

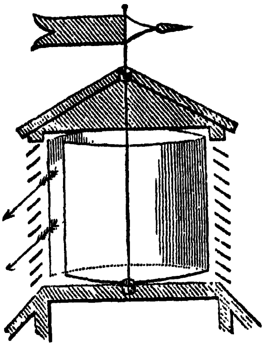

Fig. 15.

Louvred openings are not nearly so good; the aspirating effect is much less, down-draughts are common, and rain gets in. If louvres are used, a plan invented by Mr Ritchie is a good one.* Inside the louvre is a movable cylinder, turning with a vane; on the side *opposite* the wind is an opening through which the air escapes (fig. 15).

3. The movement produced by the difference of weight of unequally heated bodies of air will, of course, go on through open windows and doors, and through all the contrivances just mentioned. But as in cold climates windows and doors must sometimes be shut, no room of any kind should be without

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* Peclet (*op. cit.* t. i. p. 241) figures a variety of chimney coverings, and many others have been proposed.

additional openings, which may permit this movement from unequal temperature to go on. The great difficulty here is to exclude the action of the wind; and, in fact, it is impossible to do so; but, as far as possible, the openings should be protected from the perflating influence of the wind, so that only its aspirating force should be acting. They should be capable of being lessened in size, when the difference of the external and internal temperatures is great. As long as there are openings, movement will go on; and it does not really matter, as long as there is proper distribution, where the air comes in or goes out, or whether its direction is constant. In fact, it scarcely ever is constant, so liable is the direction to be altered by winds, by the action of the sun heating one side of a room, by the unequal distribution of heat in the room, &c. Still it seems desirable, as far as it can be done, to make such arrangements as shall give the movement of air a certain direction; and therefore, in most systems, some of the openings are intended for the admission of fresh air; and are called inlet, entrance, or adduction openings; others are intended for the discharge of impure air—and are termed exit, outlet, or abduction openings.

*Total size of all the special openings, whether intended for Inlets or Outlets.*—As the movement of air increases with temperature, the size of the apertures can only be fixed for a certain given temperature; and as the efflux of hot air increases with the height of the column (supposing the temperature is equal throughout), a different size has also to be fixed for different heights.

This causes a difficulty in fixing the proper size for ventilating openings in the case of natural ventilation, as the conditions are so variable. The theoretical size for any required change of air, supposing the conditions were constant, may be obtained from the table at page 178, which is calculated from Montgolfier's formula, with a deduction of $\frac{1}{4}$ for friction.

Thus, say that the height of the heated column is 20 feet, and the difference of temperature between the air in the room and that outside is 20°, the linear rate of discharge as stated by the table (allowance being made for friction) is 322 feet per minute, or 19,320 feet per hour. If the opening were 1 square foot, this would give 19,320 cubic feet per hour. But if 3000 cubic feet per hour are wanted for one man, the orifice of 1 square foot or 144 square inches is too large, and must be lessened in the proportion of 3000 to 19,320, $\frac{3000 \times 144}{19{,}320} = 22$ square inches (round numbers), *i.e.*, reduced to 22 square inches. There must be a corresponding space for entry, making the total ventilating opening 44 square inches.

To take another example; let us say the heated column is 15 feet, the difference of temperature 10°, and the required supply for one man 2000 cubic feet. The table gives the linear rate as 197 feet per minute, or 11,820 per hour; an orifice of 144 square inches would then give 11,820, and an orifice of 24 square inches would give 2000, $\left(\frac{2000 \times 144}{11{,}820} = 24\right)$. But if in the above conditions 3000 cubic feet hourly supply were wanted, the opening must be 36 square inches. These examples show how impossible it is to fix any size which shall meet all conditions, even if the influence of wind could be completely excluded, which is impossible. The only way is to adopt a size which will meet most cases, and supply means of altering the size according to circumstances. In this country, a size of 24 square inches per head for inlet, and the same for outlet, seems calculated to meet common conditions; but arrangements should be made for enabling this to be lessened or closed in very cold weather, or if the influence of strong winds is too much felt.[*] Moreover, the size must be in part dependent on the size of the room, because in a small room with many people it is impossible to have the size so great as it would be if each person's space were 48 square inches, unless some portion of the air were warmed.

*Relative size of the Inlets and Outlets.*—It is commonly stated that, as the heated air expands, the outlets should be larger than the inlets, and the great disproportions of 5 to 4 and 10 to 9 have been given. As, however, the average difference of temperature is only about 10° to 15° Fahr. in this country, the disproportion is much too great, as a cubic foot of air only expands to 1·020361 cubic feet with an increase of 10°. Even if the difference is 30° Fahr., a cubic foot of air only becomes 1·061 cubic feet, which is equal to an increase of about $\frac{1}{17}$th. The difference is so slight that it may be neglected, and the inlets and outlets can be made of the same size.

It is desirable to make each individual inlet opening not larger than 48 to 60 square inches in area, or enough for two or three men; and to make the outlet not more than one square foot, or enough for six men. Distribution is more certain with these small openings. It must, however, be borne in mind, that if a calculation is made for a single opening of a certain size, dividing it into a number of smaller openings causes a great loss by increasing the friction. This loss is in the ratio of the square roots of the respective areas. Proportionate allowance must of course be made.[†]

*Position and Description of the Inlet and Outlet Tubes.*—1. *Inlets.*—The air must be taken from a pure source, and there must be no chance of any effluvia passing in. As a rule, the inlet tubes should be short, and so made as to be easily cleaned, otherwise dirt lodges, and the air becomes impure. Inlets should not be large and single, but rather numerous and small (from 48 to 60 inches superficial), so that the air may be properly distributed. They should be conical or trumpet-shaped where they enter the room, as the entering air, after perhaps a slight contraction, spreads out fan-like, and a slight back-current from the room down the sides of the funnel facilitates the mixing of

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[*] The following formula proposed by Dr de Chaumont can be used instead of the table at page 178. No correction is made for friction, and therefore the sizes should be increased in the proportion of 3 to 4 if the outlets are long. It is based on Montgolfier's formula, with the discharge calculated for the hour and for square inches, instead of for the minute and the linear discharge, as in the table.

Let $h$ be the height of the heated column of air; $t$ its temperature; $t'$ the temperature of the external air; ·002 the ratio of expansion of air for each degree of Fahr.; and 100 a constant. Let D be the delivery required per hour, and $\Phi$ the total inlet and outlet area in square inches. Then to find $\Phi$:

$$\frac{D}{100\,(\sqrt{h\,(t-t') \times \cdot 200})} = \Phi$$

Example: Suppose, as in the text, that the heated column be 20 feet, its mean temperature 65°, and that of the outer air 45°, and the required delivery be 3000 cubic per hour;

$$\frac{3000}{100\,(\sqrt{20\,(65^\circ - 45^\circ) \times \cdot 002})} = 33\cdot 5$$

square inches for inlet or outlet, or 16·75 for inlet alone. Increasing this on the supposition that a quarter of the velocity is destroyed by passage through a long tube, the size of the inlet opening will be 22 square inches (round numbers).

A converse formula by Dr de Chaumont may be also useful. If the area of the inlet opening ($\Phi'$) is known, to find the delivery per hour under conditions $h$, $t$, and $t'$.

$$200\,(\sqrt{h\,(t - t') \times \cdot 002})\,\Phi' = D.$$

The constant 200 is obtained by multiplying 3600 (seconds per hour) by twice the square root of 16·09 (= 8 nearly), and dividing by 144 square inches. By halving this constant we get the number for both inlet and outlet together.

[†] Thus if we divide an opening into four parts, we shall get only one-half as much air through the four openings as we got through the single opening; so that to get the same amount with division, each part must be equal to half the original opening.

the entering air with that of the room. To lessen the risk of immediate down-draught they should turn upwards, if they are placed above the heads of the persons. Externally the inlets should be partly protected from the wind; otherwise the wind blows through them too rapidly, and, if the current be strong, draughts are felt; an overhanging shelf or hood outside will answer pretty well. Valves must be provided to partially close the openings if the wind blows in too strongly, or if the change of air is too rapid in cold weather. If covered with wire-gauze, it must be frequently cleaned.

Sometimes an inlet tube must be carried some distance to an inner room, or to the opposite side of a large room which is unprovided with cross-ventilation. In this case the heat of the room so warms the tube that the wind may be permitted to blow through it.

The position of the inlets is a matter of some difficulty. If there are several, they should be, of course, equally distributed through the room, so as to insure proper mixing of the air. They should not, however, be placed too near an outlet, or the fresh air may at once escape; theoretically, their proper place of entrance is at the bottom of the room, but if so, the air must in this climate be warmed; no person can bear the cold air flowing to and chilling the feet. The air can be warmed easily in various ways, viz:—

(*a.*) The air may pass through boxes containing coils of hot-water pipes, or (in factories) of steam pipes. This is the best mode of warming. The coils may be close to the outside wall, or in the centre, or in hospitals in boxes under the beds, communicating with the exterior air, and opening into the ward.

(*b.*) The air may pass into air-chambers behind or round grates and stoves, and be there warmed, as in the present barrack and hospital grate, contrived by Captain Galton; or as in the Meissner or Böhm stoves of Germany;* or as in the terra cotta stove, in the Herbert Hospital at Woolwich. (See WARMING.)

If the air cannot be warmed, it must not be admitted at the bottom of the room; it must be let in above, about 9 or 10 feet from the floor, and be directed towards the ceiling, so that it may pass up and then fall and mix gradually with the air of the room. The Barrack Commissioners have adopted this plan with half the fresh air brought into a barrack-room. The other half is warmed. It answers very well.

In towns or manufacturing districts the air is so loaded with particles of coal, or, it may be, other powders, that it must be filtered. Nothing answers better for this than muslin or thin porous flannel, or paperhangers' canvas, spread over the opening, which then should be made larger. This covering can be moistened if the incoming air be too dry.

The tubes proposed by Mr Tobin of Leeds provide for the introduction of air from the outside at the floor level and then up a vertical tube, about 4 feet in height; this gives a vertical direction to the current, which is retained for several feet further before it begins to spread and descend. The action of such a tube is, of course, much affected by the direction of the wind, and in some instances it is reversed altogether. The method is, however, useful in some cases, particularly for introducing air into places which could only be reached with difficulty by other means. It has been tried on a large scale at St Mary's Hospital, Paddington, with fair success.† In some forms (as made by the Sanitary Engineering Company), there is an arrangement for washing the air and arresting impurities. A somewhat similar vertical tube is advertised by Messrs Shillitoe and Shortland of Manchester. A modification for bedrooms and other rooms in private houses is also suggested by Mr Tobin, viz., to cut out slits between the sashes of the windows, so that the air enters vertically, even when the window is shut. This is similar in principle to other modifications of window ventilation already referred to, but it is only adapted for comparatively small rooms, and is quite inapplicable to a hospital ward or the like.

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* The Germans appear to be now making great use of these ventilating stoves in hospitals, and even in private houses. For a good account, see Roth and Lex, l. c, p. 248, *et seq.*

† See Dr de Chaumont's Report *op. cit.*

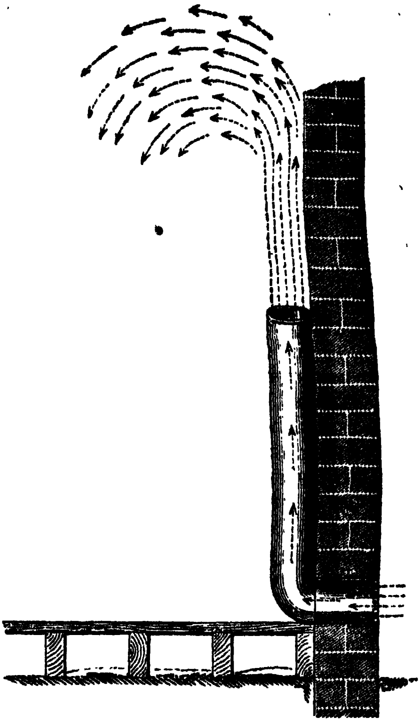

Fig. 16.—Vertical inlet tube.

2. *Outlets.*—The place for the outlets is a most important consideration, as it will determine in great measure the position of the inlets. If there are no means of heating the air passing through them, they should be at the top of the room; if there are means of heating them, they may be at any point. If not artificially warmed, the highest outlet tube is usually the point of greatest discharge, and sometimes the only one.

(*a*) *Outlet Tubes without Artificial Heat.*—They should be placed at the highest point of the room; should be inclosed as far as possible within walls, so as to prevent the air being cooled; should be straight and with perfectly smooth internal surfaces, so that friction may be reduced to a minimum. In shape they may be round or square, and they must be covered above with some apparatus (the cowl, hexagon tube, &c.), which may aid the aspirating power of the wind, and prevent the passage of rain into the shaft. The louvred openings are not the best.

The causes of down-draught and down-gusts in outlet tubes are these, the wind forces down the air; rain gets in, and, by evaporation, so cools the air that it becomes heavier than the air in the room; or the air becomes too much cooled by passage through an exposed tube, so that it cannot overcome the weight of the superincumbent atmosphere; or another outlet shaft, with greater discharge, reverses the current.

Arrangements should be made to distribute the down-draught, if it occurs; flanges placed at some little distance below, so as to throw the air upwards again before it mixes with the air of the room, or simple contrivances of a similar kind, may be used. Valves should be also fixed to lessen the area of the outlet when necessary. If there are several outlet tubes in a room, all should commence at the same distance from the floor, be of the same height (or the discharge will be unequal), and have the same exposure to sun and wind.

Simple ridge openings may be used in one-storied buildings with slanting roofs; they ventilate most thoroughly, but snow sometimes drifts in. Rain may be prevented entering by carrying down the sides of the overhanging ridge for some little distance. A flange placed some little distance below will throw any down-draught towards the walls.

(*b*) *Outlets with Artificial Warmth.*—The discharge of outlets is much more certain and constant if the air can be warmed. The chimney with open fire is an excellent outlet—so good that in dwelling-houses, if there are proper inlets, no other outlet need be made. When rooms are large, and more crowded, other outlets are necessary; the heat of the fire may be farther utilised by shafts round the chimney, opening at the top of the room, or, in other words, by surrounding the smoke-flue with foul-air shafts.

Gas, if used, should in all cases be made to warm an outlet tube, both to carry off the products of combustion, and to utilise its heat. The best arrangement appears to be to place over the gas-jet a pipe to carry off the products of combustion, and to case the pipe itself with a tube, the opening of which is at the ceiling; the tube carrying off the gas products is hot enough to cause a very considerable draught in its casing, and thus two outlet currents are in action, one over the gas, and one from the ceiling round the gas-tube. A modification of the lamp proposed in 1846 by Mr Rutter answers very well, and is now coming into use, as arranged by Mr Ricketts.

In various other ways the heat of fire and lights may be taken advantage of.

There will be seldom any difficulty in arranging the inlets and outlets, and in obtaining a satisfactory result, if these principles are born in mind, viz., to have the fresh air pure, to distribute it properly, and to adopt every means of securing the outlets from cold or of artificially warming them, and of distributing the air, which, in spite of all precautions, will occasionally pass down them.

In hot climates, when outlet shafts are run up above the general level of the building, it would be of advantage to make them of brick work, and to colour them black, so that they may absorb and retain heat.

### 5. PLANS OF TUBES AND SHAFTS WHICH HAVE BEEN PROPOSED.

In most of the plans which have been proposed, the inventors have not distinctly seen that the influence of the winds and of the movement of air produced by unequal temperatures must be carefully distinguished, and, as far as can be done, provided for.

1. *Openings at once to the Outer Air for Inlets, the Chimney being relied on for the Outlets or Special Tubes fixed in.*—Perforated or air bricks are let into the walls. A usual size is 9 × 3 inches, and the united area of all the several openings in one brick is about 11½ square inches. Another common size is 10 × 6 inches, with an open area of about 24 square inches. The wind blows freely through them, and draughts are produced.

The Sheringham valve is a great improvement on this; the air passes through a perforated brick or iron plate, and is then directed upwards by a valved opening, which can be closed, if necessary, by a balanced weight (fig. 17). The size of the internal opening is, in the usual-sized-valve, 9 inches by 3, and the area is 27 inches. These valves are usually placed towards the upper part of the room. The wind blows through them, and the movement is therefore variable. They are often outlets; it will, in fact, depend upon circumstances whether they are inlets or outlets. Very little draught is, however, caused by them, unless with a high wind; on the whole, they are the best inlets of this kind.

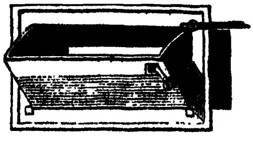

Fig. 17.

An open iron frame of the size of a brick, covered with perforated zinc, and with a valve to close it, if necessary, is a still simpler plan, and the air is pretty well distributed. The gauze should be cleaned frequently. Mr Boyle of London uses a round plate working on a screw, which can be brought nearer or farther from a corresponding opening in the wall; the air entering strikes on the plate, and then spreads circularly over the wall, and is then drawn gently into the room. Some ingenious forms of inlet and outlet have also been introduced by Mr Richard Weaver, C.E.

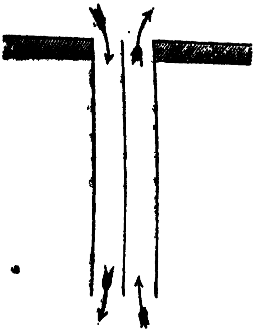

Fig. 18.

2. *Tubes of Different Kinds.*—A single tube has been sometimes used for inlet and outlet, a double current being established. This is, however, a rude plan, as there are no means of distributing the air, and as the intermingling of the current and the friction of the meeting air is sometimes so great as to impede, or even for a time stop, the movement.* To avoid these inconveniences, Watson proposed to place a partition in the tube (fig. 18), and Muir suggested the use of a double partition running from corner to corner, so as to make four tubes. He covered his divided tube with a louvre, so as to make use in some degree of the aspiratory power of the wind on one side.

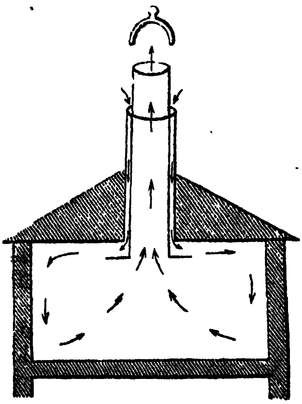

Fig. 19.

In these tubes, accidental circumstances, such as the sun's rays on one side, the wind, the fire in the room, &c., will determine which is outlet and which is inlet. They are so far better than the single tube, that the partition divides the currents and prevents friction, but there is the same irregular action and changing of currents from accidental circumstances, so that the direction of the currents and their rate are variable. The distribution of the entering air is also not good.

Much better than these plans is M'Kinnell's circular tube. It consists of two cylinders, one encircling the other, the area of the inner tube and encircling ring being equal. The inner one is the outlet tube; it is so because the casing of the other tube maintains the temperature of the air in it; and it is also always made rather higher than the other; above it is protected by a hood, but if it had a cowl turning away from the wind it would be better. The outer cylinder or ring is the inlet tube; the air is taken at a lower level than the top of the outlet tube; when it enters the room, it is thrown up towards the ceiling, and then to the walls by a flange placed on the bottom of the inner tube; the air then passes from the walls along the floor towards the centre of the room, and upwards to the outlet shaft. (Figs. 19 and 20.) Both tubes can be closed by valves. If there is a fire in the room, both tubes may become inlets; to prevent

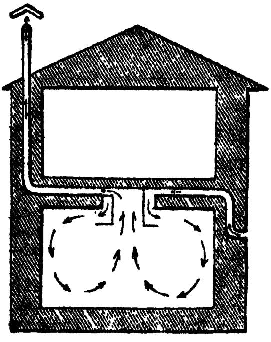

Fig. 20.

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* The model of Watson's ventilating tube is well adapted for showing how opposing currents

this the outlet tube should be closed; if doors and windows are open, both tubes become outlets.

The movement of air by this plan is imperceptible, or almost so; it is an admirable mode for square or round rooms, or small churches; for very long rooms it is less adapted.

The tube is made of all sizes, from 6 inches in diameter, which is adapted for a sitting-room, up to 7 or 8 feet, which is the size used in some churches. The two tubes, after passing out of the room, may be taken in different directions, care being taken that the inner tube is always the longest, and, if possible, with the fewest curves.

If the two tubes can be kept together for some distance, an advantage would perhaps be gained, as the hot air would transmit a portion of its heat to the air in the outer tube, which would enter the room at a higher temperature than would otherwise be the case; some loss of movement would result, but this would be trifling.

Dr J. D. Macdonald R.N., F.R.S., has proposed an ingenious form of ventilator, something on M'Kinnell's principle, but with a modification of arrangement, intended to facilitate the movement of air. The tube may be divided, either by having one tube within another (as in M'Kinnell's) or by a septum, as shown in fig. 21. A fan in the upper part of the tube determines the course of the current always in the same direction, and this fan is driven by the action of the wind upon another motile fan on the top of the tube, which may be left free, or covered with a self-adjusting cover, as in the figure. One advantage of this arrangement is that no reflux current is possible, and no rain can get down the tube.

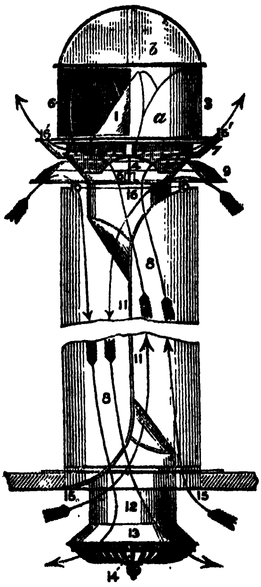

Fig. 21.*

Dr Arnott's chimney ventilator is a valved opening at the top of the room, leading at once into the chimney, and, like Dr Chowne's siphon, has the great advantage of drawing the air from the top of the room; it has been, and is, much used, but has the inconvenience of occasionally allowing the reflux of smoke.

Mr Boyle has altered this chimney ventilator by hanging small talc plates at a certain angle; falling by their own weight, they close the opening and prevent reflux, but a very slight pressure from without opens them.

Of these various plans, M'Kinnell's or Macdonald's should be chosen, if the air must be admitted at the top of the room; and they are well adapted for

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of air block each other. Although the tube is of good size, a candle placed in a bell glass, into the top of which the tube is fixed, soon goes out; a partition being then inserted into the tube, the currents are at once divided—one passes up, one down, the sides of the tube, and the candle burns again.

* 1 Motile fan. 2. Aspiratory fan. 3. Self-adjusting cap, *a* closed quarter of ditto, *b* transverse vane. 4. Spindle or axis. 5. Socket for lever point (upper socket not shown). 6. Iron frame work carrying upper socket, &c. 7. Conical band forming the upper outlet round the circular plate bearing the fans. 8. The main shaft. 9. Circular hood protecting 10. The aperture of ingress. 11. Middle longitudinal septum dividing the main shaft into two equal parts. 12. Central ingress tube. 13. Expansion of do. 14. Grating to regulate the entering air. 15. Lower aperture of ingress (circumferential). 16. Upper outlet tube. 16. Upper aperture of egress (central).

guard-rooms, cells, and rooms of small dimensions, when it is desired to have the ventilating apparatus out of reach. Watson's divided tube can also be used, but is less useful than the others.

### *System of Ventilation Adopted in the Army.*

*On Home Service.*—The official plan now in use was arranged about 18 years ago by the Barrack Improvement Commission; it is applied in most of the new barracks, and in several old ones. It has answered extremely well, and it is much to be desired that it should be carried out everywhere. It is based on the plan of natural ventilation, and consists of—

1. An outlet shaft, or more if required, proceeding from the highest point of the room; the exact position in the room varies; it is sometimes at the corner, or at one side, according to circumstances. This shaft is carried straight up inside the wall, and about 4 to 6 feet above the roof, and is covered with a louvre. It is made of wood, is very smooth inside, and is provided with a flap for partly closing it below. Its size is regulated by that of the room and by the number of inmates, but it is not made larger than 1 square foot; if more outlet is required, another shaft is put up. The relation between its size and that of the room varies with the position of the room. In a three-storied barrack the rule is as follows:—

1. On the ground floor, 1 square inch of section area of outlet shaft for every 60 cubic feet of room space, or for each man 10 square inches of area.
2. On the first floor, 1 square inch for every 55 cubic feet of room space, or for each man 10·9 (say 11) square inches.
3. On the second floor, 1 square inch for every 50 cubic feet of room space, or for each man 12 square inches.

In a one-storied barrack the amount should be the same as the second floor, or, in other words, 12 men would have a shaft of 1 square foot. In addition, there is the chimney, which, with Galton's stove, gives a section area per head of about 6 square inches. The total outlet area per man is therefore 16 to 18 inches, according to circumstances.

2. *Inlets.*—The amount of inlet is a trifle more than 1 square inch to every 60 cubic feet of room.

Half the inlet air is warmed in all the new barracks and many old barracks by being taken through air-chambers behind the fire (area of tube = 6 square inches per head), and the other half comes direct from the outer air into the rooms through Sheringham valves. Area of outer opening = 5 square inches, making altogether 11 square inches of inlet opening per man.

The cold air inlets (Sheringham valves) are placed at the sides near the ceiling, about 9 feet from the floor, and are not opposite each other. Fig. 22 shows a usual arrangement. The outlet space is thus seen to be rather larger than the inlet, but as the doors and windows seldom fit close, it is probable that practically this is of little consequence.

The movement of air through these openings is tolerably regular—as regular as it ever can be in natural ventilation. The discharge of air through the chimney and outlet shaft averages about 1200 cubic feet per head per hour,

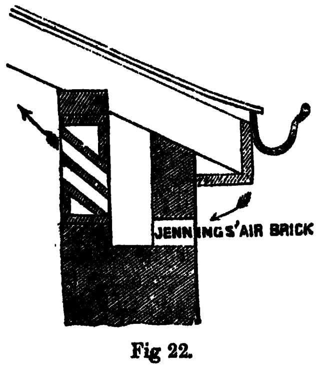

Fig 22.

with a range from 700 to 1500 or 1600, according to the amount of fire, the warmth of the room, and the movement of the external air. The usual upward current through the outlet shafts at night, is from 3 to 5 feet per second. Sometimes the chimney and outlet a little counteract each other; a strong chimney draught may stop the current in the outlet shaft, but there is seldom any down-draught unless rain beats into the louvre and trickles down the inside of the shaft. The ventilation of barracks has been wonderfully improved by this plan, and the average carbonic acid ranges from ·7 to 1 per 1000 volumes, according to the rapidity of movement of the air.

The hospital system is precisely the same, except that the dimensions are nearly doubled.

*Mediterranean Stations.*—The same system is directed to be carried out whenever practicable at Malta and Gibraltar, only the size of the inlets and outlets are trebled; for example, there is 1 square inch of outlet for every 20 cubic feet of space instead of 60 as at home; great care is ordered to be taken to remove all outside obstacles to the movement of the wind.

*The Tropics and India.*—The same system in principle is now directed to be used in India.

## SECTION III.

## ARTIFICIAL VENTILATION.

Artificial ventilation is accomplished in two ways; either the air is drawn out of a building or room (the method by extraction), or it is driven in, so as to force out the air already in the room (the method by propulsion).

### SUB-SECTION 1.—VENTILATION BY EXTRACTION.

This is produced by the application of heat, so as to cause an upward current, or by the steam jet, or by a fan or screw, which draws out the air.

1. *Extraction by Heat.*—The common chimney is a well known example of this. There is a constant current up the chimney, when the fire is burning, in proportion to the size of the fire and of the chimney. The usual current up a common sitting-room chimney, with a fair fire, is, as measured by an anemometer, from 3 to 6 feet per second. A very large fire will bring it up to 8 or 9 feet. The movement caused by a kitchen or furnace fire is, of course, greater than this. If the area of the section where the anemometer is placed be known, the discharge can be stated in cubic feet.

When the air enters equably, and is well distributed, the movement of air is from the inlets gently towards the fire-place; there is also said to be a movement, from above the fire-place, along the ceiling and down the walls, and then along the floor to the chimney. (Reid and Stewart, quoted by the Barrack Commissioners.)

In the wards of Fort Pitt the current, with a good fire, is about 3½ to 4½ feet per second; and as the section area of the throat is ·5 square foot, the average discharge is about 7200 cubic feet per hour. In the barracks of Chatham, Dr Fyffe found the discharge by the chimney to be 9080 cubic feet per hour (average of six observations). In the barracks at Gravesend, Messrs Hewlett, Stanley, and Reid found the discharge to be 6120 cubic feet per hour (average of twenty observations). At Chelsea New Barracks, with a fire alight but low, the velocity was 14·6 per second, or 21,038 cubic feet per hour; and, with the fire out, 11·9 per second, or 17,088 per hour.* In the experiments of the Barrack Commissioners,* the chimney discharge ranged from 5300 to 16,000 cubic feet per hour, the mean of twenty-five experiments being 9904 cubic feet. Even in summer, without a fire, there is generally a good up-current.† It may be then concluded that, with an ordinary fire, a chimney gives a discharge sufficient for four or five persons. If, then, more than this number of persons habitually live in the room, another outlet must be provided.

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* Dr F. de Chaumont's Reports, Army Med. Reports, vol. ix.

As the current up the chimney is so great when the fire is lighted, all other openings in a room, if not too many, become inlets; and, in this way, down-draughts of air may occur from tubes intended as outlets. There is no remedy for this; and if too much enters, the outlets must be more or less closed.

If the room be without openings, so that no air can reach the fire, air is drawn down the chimney, and a double current is established, by which the fire is fed. The down-current coming in puffs is one cause of smoky chimneys, and may be at once cured by making an inlet.

The chimney and fire is a type of a number of other similar modes of ventilation by extraction.

The ventilation of mines is carried on by lighting a fire at the bottom of a shaft (the upcast or return shaft), or half a shaft, if there be only one. The air is drawn down the other or downcast or intake shaft, or half the shaft, and is then made to traverse the galleries of the mine, being directed this way or that by partitions. Double doors are used, so that there is no back or side rush of the air. The current passes through the upcast-shaft at the rate of from 8 to 10 feet per second; it flows through the main galleries at the rate of from 4 to 6 feet per second, or even more, and from 1000 to 2000 cubic feet per head per hour are supplied in good mines. In fire-damp mines much more than this is given, even as much as 6000 cubic feet per man per hour. ("Proceedings of Civil Engineers," vol. xii. p. 308). If the quantity of air be reduced too low there is a serious diminution in the amount of work performed by the men. A horse is said to require 2466 cubic feet, and a light 59 cubic feet per hour. It may easily be conceived how skilfully the air must be directed, so as to traverse the most remote workings; in some mines a portion of air makes a circuit of from 30 to 40 miles before it can arrive at the upcast-shaft. The size of the shafts in a colliery varies from 8 to 11 or 12 feet in diameter; the sectional area of a shaft of the former size would be 50 square feet. A current of 8 feet per second in the upcast-shaft would give a discharge of 1,440,000 cubic feet per hour, which would give 720 men 2000 cubic feet per hour.

The sectional area and height of the extracting shaft, and of the tubes running into it, have been fixed by Péclet; the principle is to give to the shaft the greatest height which can be allowed, and the largest section which can be given,‡ without permitting the temperature of the contained air to fall so low as to be unable to overcome the resistance of the atmosphere at the top of the shaft, or the action of the winds.§

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* Report, 1861, p. 73.

† In August 1869 I found at Fort Elson the velocity to be on one occasion 7·5 per second and at Gosport New Barracks, 8·4. The velocity generally ranges from 1½ feet to 3 feet per second, although it is often more. (F. de C.)

‡ De la Chaleur, 3d ed. 1861, t. iii. p. 66, *et seq.*

§ The amount of the resistance given to the movement of air through the tubes leading to the shaft, and in the shaft itself, can be calculated from the formula given by Péclet at p. 47 (t. iii.), but which it is unnecessary to introduce here. General Morin's observations show that the difference in the volumes of air passing through small openings is in the ratio of the square root of the area. The increased velocity through the smaller openings does not compensate for this great loss. The shape of the tubes ought also to be considered, the least resistance being given by a circular aperture. For a table of friction due to form of sectional area, see "Hygiene" in *Sanitary Record*, 1875, by Dr F. de Chaumont.

In large buildings the same plan is often used; a chimney (*cheminée d'appel* of the French) is heated by a fire at the bottom, and into the bottom of this shaft, close to the fire, run a number of tubes coming from the different rooms. Several French and English hospitals, and many other buildings, are ventilated in this way. Dr Reid for some years ventilated the Houses of Parliament in the same manner, and so powerful was his up-draught, that he could change the entire air in the building in a few minutes.

In dwelling-houses it has been proposed to have a central chimney, into which the chimneys of all the fires shall open, and to surround this with air-shafts connected with the tops of the rooms. It is supposed that, if other inlets exist, there will be a current both up the chimney and up the shaft running beside it.

In all these cases it requires that the workmanship shall be very exact, so that air shall not reach the extracting shaft except through the tubes.

It is now about a hundred and twenty years ago since Dr Mead brought before the Royal Society Mr Sutton's plan of ventilating ships on the same principle. Tubes running from the hold and various cabins joined together into one or two large tubes which opened into the ashpit beneath the cooking fires. If the doors of the ashpits were kept closed, the fires drew the air rapidly from all parts of the ship. Unfortunately, this plan never came into general use. The same plan was adopted by Dr Mapleton for the ventilation of the hospital ships employed in the last (1860) China War. The arrangement requires some watching to prevent careless cooks from allowing air to reach the fires in other ways.

On the same principle some men-of-war are now being ventilated.* The funnel and upper part of the boiler, and, as far as possible, all the steam apparatus, are inclosed in an iron casing, so that a space is left of some 3 or 4 feet between the casing and the funnel. When the fires are lighted, there is of course a strong current up this space, and to supply this the air is drawn down through all the hatchways towards the furnace doors. The temperature of the stoke-hole is reduced from 130° or 140° Fahr., to 60° and 70°; and the draught to the fires is so much more perfect, that more steam is obtained from the same amount of fuel. This plan, devised by Mr Baker, has been ingeniously applied by Admiral Fanshawe, late superintendent at Chatham dock-yard, to the ventilation of every part of the ship where there are no water-tight compartments. Edmond's plan combines with this the ventilation not only of the hold, but of the timbers of the ship.

Sometimes, instead of a fire at the bottom of the chimney, it is placed at the top; but this is a mistake, as there is a great loss of heat from the immediate escape of the heated air; the proper plan is to heat, as much as possible, the whole column of air in the chimney, which can only be done by placing the fire below.

Frequently, instead of, or in addition to a fire, heat is obtained in the shaft by means of hot water or steam pipes. This plan has long been in use in England,† and has since been introduced into France, and improved by M. Léon Duvoir. Warming, as well as ventilation, is accomplished by this method, which is in action at the Hospitals Lariboisière (in one-half) and Beaujon. It appears to be at once effectual and economical, though it has been sharply criticised by Grassi and Péclet. After a very long investigation into the merits of all rival plans, it was adopted by a French Commission for

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* In the new ironclads it is found necessary to use large fans driven by special engines to effect thorough change of air below.

† It is in use in the Circuit Court-House in Glasgow, and in the Police Buildings at Edinburgh (Ritchie), and in many other buildings.

It is certainly true that the ventilation by this plan is irregular;[†] and also, that in the Hospital Lariboisière, a much greater quantity of air passes through the extracting shaft than enters through the hot-water stoves.

In the summer, when there is ventilation without warming, the outflow of air from the wards varied from 84·4 cubic metres (2980 cubic feet) to 55·3 cubic metres (1952 cubic feet) per head per hour.[‡]

In the winter, when there are both ventilation and warming, the outflow of air from the wards was 82·2 cubic metres or 2902 cubic feet, per head per hour. Of that amount, only 35 cubic metres (1235 cubic feet) entered by the water-stoves, the rest came in by doors and windows and other openings—an objectionable point, as the air might press in from the closets. Yet, in spite of this, the temperature was maintained pretty well up to the limit fixed in the agreement, viz., 15° cent. or 59° Fahr.

Oil has been used in some cases instead of water.

Very frequently, instead of a fire or hot-water vessels, lighted gas is used to cause a current, and if the gas can be applied to other uses, such as lighting, cooking, or boiling water, the plan is an economical one.

In theatres the chandeliers have long been made use of for this purpose. M. D'Arcet proposed this for several of the old theatres in Paris, and the Commission[§] appointed to determine the mode of ventilation to be adopted in the Théatres Lyrique et du Cirque Impérial, have determined, after much consideration, that this plan is the best adapted for theatres. The details have, however, been somewhat modified from those devised by D'Arcet, and are too long to be here inserted, but they seem admirably adapted to distribute the entering air thoroughly, and to insure its discharge. The entering air is warmed by caloriféres below the pit, and is then carried by flues to the front of the stage, and to the front of each tier of boxes, where they open at the floor. The outgoing air is drawn away by flues running from each box, and ending in a large central shaft surrounding the tube which carries off the products of the combustion of the central chandelier. But every gas-jet in the house, as well as the spare heat of the furnace, is made to contribute its share of movement.

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[*] Two excellent reports have been made by this Commission, of which General Morin is reporter. Their titles are given farther on. Much information is also given in General Morin's work on ventilation, Etudes sur la Ventilation, Paris, 1863, 2 vols.

[†] Péclet—Traité de la Chaleur, 1861, t. iii. p.267.

[‡] Grassi, *op. cit.* pp. 35–37.

[§] Rapport de la Commission sur le Chauffage et la Ventilation du Théatre Lyrique et du Thèatre du Cirque Impèrial. Rapporteur le General Morin. Paris, 1861.

The amount which can be supplied in winter is 30 cubic metres (= 1059 cubic feet) per head per hour. The burning of 20 cubic metres (706·2 cubic feet) of gas in one hour at the Opera Comique caused the discharge of 80,000 cubic metres of air (2,825,280 cubic feet). The temperature of the air was 9° cent. or 16° Fahr. above the external air. At the Vaudeville, 10 cubic metres (353 cubic feet) of gas was consumed per hour, and 15,523 cubic metres (548,210 cubic feet) passed through the chimney, so that 1 cubic foot of gas perfectly consumed caused the discharge of 1553 cubic feet of air. General Morin, from numerous experiments, found that 1 cubic metre of gas caused the discharge of 1000 cubic metres of air, or 1 cubic foot would cause the discharge of 1000 cubic feet of air.*

The advantage of extraction by heat, especially in the case of theatres and buildings where gas can be brought into play, are obvious.

There are some objections to extractions by the fire and hot-air shaft.

(1.) The inequality of the draught. It is almost impossible to keep the fire at a constant height. The same quantity of combustible material should be consumed in the same time every day, and the heat should be kept in by large masses of masonry. Still, with these precautions, the atmospheric influences, and changes in the quality of the combustibles, cannot be avoided.

(2.) The inequality of the movement from different rooms. From rooms nearest the shaft, and with the straightest connecting tubes, there may be a strong current, while from distant rooms the friction in the conduits is so great that little air may pass. The greatest care is therefore necessary in calculating the resistance, and in apportioning the area of the tubes to the resistance. This plan is, indeed, best adapted for the compact buildings. Occasionally, if the friction be great, from too small size, or the angular arrangement of the conduits leading to the hot-shaft, there may be no movement at all in the conduits, but a down-current to feed the fire is established in the shaft itself—a state of things which was discovered by Dr Sanderson to exist in the ventilation of St Mary's Hospital in London.

(3.) The possibility of reflux of smoke, and perhaps of air, from the shaft to the rooms, is another objection of some weight.

(4.) The impossibility of properly controlling the places where fresh air enters. It will flow in from all sides, and possibly from places where it is impure, as from closets, &c.; air is so mobile that with every care it is difficult to bring it under complete control—it will always press in and out at the point of least resistance.

2. *Extraction by the Steam-jet.*—The moving agent here is the force of the steam-jet, which is allowed to pass into a chimney. The cone of steam sets in motion a body of air equal to 217 times its own bulk. Tubes passing from different rooms enter the chimney below the steam-jet, and the air is extracted from them by the strong upward current. This plan is best adapted for factories with spare steam. It was employed for some time in the ventilation of the House of Lords, but was finally abandoned.

3. *Extraction by a Fan or Screw.*—An extracting fan or Archimedean screw has been used to draw out the air. Several different kinds have been proposed by Messrs Combes, Letoret, Glepin, and Lloyd, and have been used in coal mines in Belgium, and in some of the English mines. At the Abercarn mine, in South Wales, a fan is used of 13½ feet diameter; the vanes, eight in number, are 3½ feet wide by 3 feet long; at 60 revolutions per minute the velocity of the air is 782 linear feet per minute, and 45,000 cubic feet are

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* Etudes sur la Vent, t. ii. p. 720.

extracted; the velocity at the circumference of the fan is 2545 feet per minute; the theoretical consumption of coal per hour is 17·4 lb.[*]

Mr Van Hecke formerly used a fan for this purpose, in his system of ventilation of buildings, but he has found it better to abandon it, and substitute a propelling fan. It was proposed by Mr Higgins to put in a chimney an Archimedean screw to be turned by the wind, and in this way it was thought a constant upward current would be caused. But the plan has little power, and is not now employed.

To both these methods of extraction some of the objections already noted apply, but extraction by the fan is, of course, more uniform.

### SUB-SECTION II.—VENTILATION BY PROPULSION.

This plan was proposed by Desaguliers, in 1734,[†] when he invented a fan or wheel inclosed in a box. The air passed in at the centre of the fan, and was thrown by the revolving vanes into a conduit leading from the box. In some form or other this fan has been used ever since, and the conduits leading from it are now generally made large, so that the fan may move slowly, and deliver a large quantity of air at a low velocity. The fan, if small, is worked by hand; if larger, by horse, water, or steam power.

The fans are often made with six or eight rays, each carrying vanes at the end, which should be as close as possible to the enveloping box. In size, the length of the vanes should be more than half the length of the rays; the number of rays should augment with the diameter of the orifice of access.[‡] (Péclet, p. 259.)

The amount of air delivered can be told by timing the speed of revolution of the extremities of the fan per second, or per minute; the effective velocity is equal to ¾ths of this, and this is the rate of movement of the air. If the section area of the conduit be known, the number of cubic feet discharged per second, minute, or hour can be at once calculated.

The power of this plan is very considerable. With a fan of 10 feet diameter, revolving sixty times per minute, the effective velocity is 1414 feet per minute. The rate of movement in the main channel should not be more than 4 feet per second; the conduits must gradually enlarge in calibre; and the movement, when the air is delivered into the rooms, should not be more than 1½ feet per second.

At the Hospital Lariboisière in Paris, it is stated that 150 cubic metres (=4296 cubic feet) have been delivered per head per hour, in the wards ventilated by the propelling fan of MM. Thomas et Laurens. It must, however, be remembered, that the later observations of General Morin have shown that much of the movement ascribed to the fan was really owing to natural ventilation.

This plan is very well adapted for those cases in which a large amount of air has to be suddenly supplied, as in crowded music halls and assembly rooms. St George's Hall at Liverpool is ventilated in this way. The air is taken from the basement; is washed by being drawn through a thin film of water thrown up by a fountain; is passed into calorifères (in the winter), where it can be moistened by a steam-jet, if the difference of the dry and wet bulb be more than four or six degrees, and is then propelled along the channels which distribute it to the hall. In summer, it is cooled in the conduits by the evaporation of water.

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[*] Ure's Dictionary, 1860; art. Ventilation, vol. iii. p. 961.

[†] Course of Experimental Philosophy, vol. ii. p. 564. The wheel was shown to the Royal Society in 1734.

[‡] Péclet, De la Chaleur, 3d edition, 1868, t. i. pp. 259, 263. Numerous kinds of fans for propulsion and extraction are figured, and detailed accounts of construction and amount of work are given.

At the Hôpital Necker in Paris, and in many other places, the plan of Van Hecke is in use. A fan, worked by an engine, drives the air into small chambers in the basement, where it is warmed by cockle stoves, and then ascends into the rooms above, and passes out by outlet shafts constructed in the walls. The system is effective and economical, though it is only just to say that, the use of the fan excepted, it is precisely similar in principle to Sylvester's.

In addition to the fan, other appliances have beeen used. Soon after Desaguliers proposed the fan, Dr Hales employed large bellows for the same purpose, and they were used for some time on board some men-of-war, and in various buildings. They were worked by hand; and probably this, and their faulty construction, led to their being disused. Their use has been revived, and their form modified and improved by Dr Arnott* (fig. 23). Dr Arnott has shown that Hales lost much power by forcing his air through small openings; and, by some ingenious alterations, has made an effective machine. It is a large box or cylinder, in which a piston works; openings are made at the ends of sufficient size; oiled silk hangs over the upper openings on the *inside*, and on the lower openings on the *outside* of the box. These covers, therefore, act as valves, and allow the air to pass in one direction only; as the piston moves, air is driven through the lower openings, on the side towards which the piston is moving, while fresh air enters at the same time through the upper openings at the opposite end. A pump of 6 feet long, 4 feet wide, made of deal boards, and fitted with a piston of wood, can be constructed in a few hours, and will deliver 96 cubic feet at every stroke.

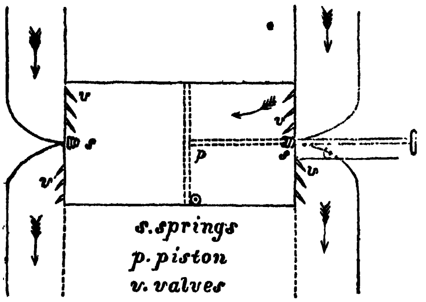

Fig. 23.

Dr Arnott has also fitted up a gasometer pump, which was used in the York County Hospital for some time, but was finally disused, probably because the apparatus, though excellent in principle, was not quite large enough. The hydraulic air-pump, sometimes used in mines, is useful on a small scale.†

The punkah used in India is another mechanical agent with a similar though more imperfect action. When a punkah is pulled in a room open on all sides, it will force out a portion of air, the place of which will be at once supplied by air rushing in with greater or less rapidity from all points. If the punkah can be moistened in any way, its cooling effect is considerable. Captain Moorsom, of the 52d Regiment, some years ago proposed an ingenious plan, which is given in the Indian Sanitary Report. A wheel turned by a bullock both moves the punkah, and elevates water, which then passes along the top of the punkah, and flows down it.

The advantages of ventilation by propulsion are its certainty, and the ease with which the amount thrown in can be altered. The stream of air can be taken from any point, and can, if necessary, be washed by passing through a

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[*] On the Smokeless Fireplace, by Neil Arnott, M.D., F.R.S., &c., 1855, p. 162; and in other publications. In the figure all the valves are shown open, but, during action, the top valves on one side, and the bottom on the other, are alternately open or closed.

[†] Ure's Dictionary, 1860, vol. ii. p. 953.

thin film of water, or through a thin screen of moistened cotton, and can be warmed or cooled at pleasure to any degree. In fact, the engineer can introduce into this operation the precision of modern science.

The disadvantages are the great cost, the chances of the engine breaking down, and some difficulties in distribution. If the air enter through small openings, at a high velocity, it will make its way to the outlets without mixing. The method requires, therefore, great attention in detail.

## SECTION IV.

## RELATIVE VALUE OF NATURAL AND ARTIFICIAL VENTILATION.

Circumstances differ so widely, that it is impossible to select one system in preference to all others. In temperate climates, in most cases, especially for dwelling-houses, barracks, and hospitals, natural ventilation, with such powers of extraction as can be got by utilising the sources of warming and lighting, is the best. Who, in fact, would not attempt to make use of these vast powers of nature which are ever ready to serve us? Incessant movement of the air is a law of nature. We have only to allow the air in our cities and dwellings to take share in this constant change, and ventilation will go on uninterruptedly without our care.

In some circumstances, however, as in the tropics, with a stagnant and warm air; and in temperate climates in certain buildings, where there are a great number of small rooms, or where sudden assemblages of people take place, mechanical ventilation must be used. So much may be said both for the system of extraction and propulsion under certain circumstances, that I think it is impossible to give an abstract preference to one over the other. This is evident, indeed, from the fact, that quite contrary opinions have been arrived at by equally competent men. Péclet, whose great authority no one can doubt, says (De la Chaleur, t. iii. p. 63), "Mechanical ventilation has then an immense advantage over the ventilation of an extracting chimney" (*cheminée d'appel*); and Grassi, from a comparison of the two plans at the Lariboisière Hospital, unequivocally condemned the system of extraction as arranged by Duvoir. Yet, lately, General Morin, after a fresh inquiry into the whole subject, has as decidedly pronounced the system of propulsion to be everywhere inferior to that by extraction. He has also condemned the plan of Van Hecke, which previously had been praised by Pettenkofer. In fact, it is evident that the special conditions of the case must determine the choice, and we must look more to the amount of air, and the method of distribution, than to the actual source of the moving power. But in either case the greatest engineering skill is necessary in the arrangement of tubes, the supply of fresh air, &c. The danger of contamination of air as it passes through long tubes, and the immense friction it meets with, must not be overlooked. For hospitals, I cannot but believe natural ventilation is the proper plan. The cost of the various plans will depend entirely on circumstances; the nature of the building; the price of materials, coal, &c. On the whole, the plans of ventilating and warming by hot-water pipes, and Van Hecke's plan, are cheaper than the method by propulsion by means of a large fan; but the latter gives us a method which is more under engineering control, and is better adapted for hot climates when it is desired to cool the air.

# CHAPTER IV.

## EXAMINATION OF AIR AND OF THE SUFFICIENCY OF VENTILATION.

THE sufficiency of ventilation should be examined—

1*st*, By determining the amount of cubic space assigned to each person, and the amount of movement of the air, or, in other words, the number of cubic feet of fresh air which each person receives per hour.

2*d*, By examining the air by the senses, and by chemical and mechanical methods, so as to determine the presence, and, if possible, the amounts of suspended matters, organic vapour, carbonic acid, sulphuretted hydrogen, and watery vapour.

## SECTION I.

### MEASUREMENT OF CUBIC SPACE.*

The three dimensions of length, breadth, and height are simply multiplied into each other. If a room is square or oblong, with a flat ceiling, there is, of course, no difficulty in doing this, but frequently rooms are of irregular form, with angles, projections, half-circles, or segments of circles. In such cases the rules for the measurement of the areas of circles, segments, triangles, &c., must be used. By means of these, and by dividing the room into several parts, as it were, so as to measure first one and then another, no difficulty will be felt. After the room has been measured, recesses containing air should be measured and added to the amount of cubic space; and, on the other hand, solid projections, and solid masses of furniture, cupboards, &c., must be measured, and their cubic contents (which take the place of air), deducted from the cubic space already measured. The bedding also occupies a certain amount of space; a soldier's hospital mattress, pillow, three blankets, one coverlet, and two sheets, will occupy almost 10 cubic feet, about 7 if tightly rolled up. It is seldom necessary to make any deduction for tables, chairs, and iron bedsteads, or small boxes; it is a refinement to do this, or to reduce the temperature of the air to standard temperature, as is sometimes done.

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* The following are some useful measures :—

1 cubic foot, . . . . . . = 1728 cubic inches.
" " . . . . . . = 28·31 French litres.
1 pint, . . . . . . . = 34·66 cubic inches.
1 fluid ounce, . . . . . . = 1·733 " "
1 cubic metre (French), . . . . = 85·31658 cubic feet (English).
1 litre (French), . . . . . . = 0·035316 cubic feet.
1 litre, . . . . . . . = 61·027 cubic inches.
1 cubic centimetre, . . . . = 0·06103 cubic inches.

Cubic centimetres are to cubic inches as 16·4 to 1.

The Prussian foot is equal to 12·357 inches, or 1·0298 English feet, and the cubic foot Prussian is equal to 1·092 cubic feet English, or almost 1·10th more. The Prussian square foot is equal to 152·7 square English inches, or 1·0605 English square feet. One English square foot is equal to ·9429 Prussian square feet.

A deduction must be made, however, for the bodies of persons living in the room; a man of average size takes the place of about 2½ to 4 cubic feet of air (say 3 for the average).*

In linear measurement, it is always convenient to measure in feet and decimals of a foot, and not in feet and inches.† If square inches are measured, they may be turned into square feet by multiplying by ·007.

### Rules—*Area or Superficies.*

*Area of circle,* = $D^2 \times \cdot 7854$.
" " = $C^2 \times \cdot 0796$.
*Circumference of circle,* = $D \times 3 \cdot 1416$.
*Diameter of circle,* = $C \div 3 \cdot 1416$.
*Area of ellipse,* = Multiply the product of the two diameters by ·7854.
*Circumference of ellipse,* = Half sum of the two diameters by 3·1416.
*Area of rectangle,* = Multiply two sides.
*Area of parallelogram,* = Multiply a side by its width on the square.
*Area of trapezium,* = Multiply ½ sum of the two perpendiculars by the diagonal on which they fall; *or*

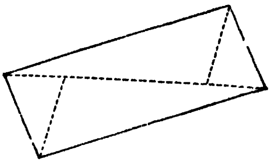

Fig. 24.

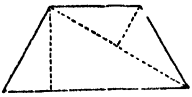

Fig. 25.

Divide into two triangles in the most convenient manner, calculate the areas, and take the sum.

*Area of trapezoid,* = Take ½ the sum of the parallel sides and multiply by the distance between them.

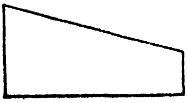

Fig. 26.

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* The weight of a man in stones, divided by 4, gives the cubic feet he occupies. Thus a man weighing 12 stones occupies 3 cubic feet.

† The following table may be found convenient:—

| Inches. | | Decimal parts of a foot. | Inches. | | Decimal parts of a foot. |
|---|---|---|---|---|---|
| 12 | = | 1·00 | 6 | = | 0·50 |
| 11 | = | 0·92 | 5 | = | 0·42 |
| 10 | = | 0·83 | 4 | = | 0·33 |
| 9 | = | 0·75 | 3 | = | 0·25 |
| 8 | = | 0·67 | 2 | = | 0·17 |
| 7 | = | 0·58 | 1 | = | 0·08 |

*Area of triangle*, . . . . . = Base × ½ height, or Height × ½ base.

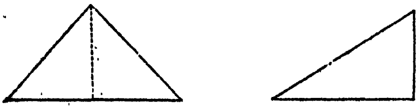

Fig. 27.

*Area of segment of circle*, . . . = To ⅔ of product of chord and height add the cube of the height divided by twice the chord

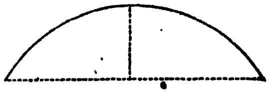

Fig. 28.

$$(Ch \times H \times \tfrac{2}{3}) + \frac{H^3}{2\,Ch}$$

*Cubic Capacity of a Cube.*—Multiply the three dimensions, length, breadth, and height.

*Cubic Capacity of a Cone or Pyramid.*—Area of base × ⅓ height.

*Cubic Capacity of a Cylinder.*—Area of base × height.

*Cubic Capacity of a Parallelepiped.*—Multiply area of one side by the perpendicular let fall on it.

*Cubic Capacity of a Dome.*—Two-thirds of the product of the area of the base multiplied by the height (area of base × height × ⅔).

*Cubic Capacity of a Sphere.*—$D^3 \times \cdot 5236$.

The cubic capacity of a bell-tent may be taken as that of a cone.

The cubic capacity of an hospital marquee must be got by dividing the marquee into several parts—1*st*, into body; and 2*d*, roof:—

1. Body, as a solid rectangle, with a half cylinder at each end.
2. Roof, solid triangle, and two half cones.

The total number of cubic feet, with additions and deductions all made, must then be divided by the number of persons living in the room; the result is the cubic space per head.

## SECTION II.

## MOVEMENT OF AIR IN THE ROOM.

The direction of movement must first be determined, and then its rate.

### 1. DIRECTION OF MOVEMENT.

First enumerate the various openings in the room—doors, windows, chimney, special openings, and tubes—and consider which is likely to be the direction of movement, and whether there is a possibility of thorough movement of the air. Then, if it is not necessary to consider further any movement through open doors or windows, close all these, and examine the movement through the other openings. This is best done by smoke disengaged from smouldering cotton-velvet, and less perfectly by small balloons, light pieces of paper, feathers, &c. The flame of a candle, which is often used, is only moved by strong currents. It may be generally taken for granted that one-half the openings in a room will admit fresh air, and half will be outlets. But this is not invariable, as a strong outlet, like a chimney, may draw air through an inlet of far greater area than itself, or may draw it through a much smaller area, with an increased rapidity.

### 2. RATE OF MOVEMENT.

The direction being known, it is only necessary to measure the discharge through the outlets, as a corresponding quantity of fresh air must enter.

*By the Anemometer.*—This is best done by an anemometer, or air-meter, of which there are several in the market. The one commonly used is that invented by Combes in 1838: four little sails, driven by the moving air, turn an axis with an endless screw, which itself turns some small toothed wheels, which indicate the number of revolutions of the axis, and consequently the space traversed by the sails in a given time, say one minute. M. Neumann, of Paris, has modified this anemometer by omitting most of the wheels, and introducing a delicate watchmaker's spring, which opposes the force of the wind, and when it equals it, brings the sails to a stand-still. By a careful graduation (which must be done for each instrument), the rate per second is determined, and is indicated by a small dial and index.

Mr Casella of Hatton Garden, has, at my suggestion, modified and improved this instrument, and has adapted it to English measures. A very beautiful instrument is thus available at a comparatively low price, by which the movement of air can be measured very readily.

Casella's air-meter is thus used:—Being set at the zero point, it is placed in the current of air; if it is placed in a tube or shaft, it should be put well in, but not quite in the centre, as the central velocity is always greater than that of the side; a point about two-fifths from the sides of the tube will give the mean velocity. The time when the sails begin to move is accurately noted, and then, after a given time, the instrument is removed, and the movement, in the time noted, is given by the dial. A correction is then made, if the instrument requires it, and the linear discharge is obtained.* If this linear discharge is multiplied by the section-area of the tube or opening (expressed in feet or decimals of a foot), the cubic discharge is obtained. If the current varies in intensity, the movement should be taken several times, and the mean calculated; and if the tube is so small that the sails approach closely to the circumference, the results cannot be depended on. If placed at the mouth of a tube, it often indicates a much feebler current than really exists in the tube.

The cubic discharge per minute being known, the amount per hour is got by multiplying by 60, and this, divided by the number of men in the room, gives the discharge per head for that particular aperture.

An anemometer on a larger scale is fixed in some of the large outlets of the Paris hospitals, showing the movement at every moment by means of an index and dial.†

*By the Manometer.*—Dr Sanderson has made an ingenious alteration of a manometer described by Péclet, which can also be employed to measure the pressure, and by calculation the velocity, of the air. The current of air is allowed to impinge on a surface of water, and the height to which the water is driven up a tube of known inclination and size gives at once a measure of force. But, as necessitating a little calculation, this instrument is less useful than the anemometer, though it is adapted for cases where the anemometer cannot be used, as it may be connected by a long tube with a distant room, and probably would be well fitted to measure constantly the velocity in an extraction shaft.

In measuring the movement of the air in chimneys, or places whether either the heat or the dust would injure the air-meter, a manometer must be used. Mr Fletcher describes what appears to be a good one.‡

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* All instruments require correction, as they never give the whole of the velocity. In Casella's newest forms the correction is additive and uniform for all velocities.

† Péclet—De la Chaleur, t. i. p. 171, where the description will be found.

‡ Fifth Annual Report of the Inspector under the Alkali Act, Blue Book.

*By Calculation.*—Supposing the external air is tranquil, and that the only cause of movement is the unequal weights of the external colder and the internal warmer air, the amount of discharge may be approximately obtained by the law of Montgolfier, described in the chapter on VENTILATION. There is a fallacy, however, as the amount of friction can never be precisely known. Still, as an approximation, and in the absence of an anemometer, the rule is useful; and I have therefore calculated a table as follows.

On testing this table, however, by the air-meter, I have found it give too much when the tubes are long, on account of the great friction, and I would therefore advise the further deduction of ⅙th when the shaft or tube is long, and is at the same time of small diameter. If the tube has many angles, or is greatly curved, this table is too imperfect to be used.

TABLE *to show the Discharge of Air in linear feet per minute. Calculated from Montgolfier's formula; the expansion of air being taken as* 0·002 *for each degree Fahrenheit, and one-fourth being deducted for friction.* (*Round numbers have been taken.*)

| Height of column. | DIFFERENCE BETWEEN INTERNAL AND EXTERNAL TEMPERATURE. | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 30 |
| 10 | 88 | 102 | 114 | 125 | 135 | 144 | 153 | 161 | 169 | 176 | 183 | 190 | 197 | 204 | 210 | 216 | 222 | 228 | 233 | 239 | 244 | 249 | 254 | 279 |
| 11 | 92 | 107 | 119 | 131 | 141 | 151 | 160 | 169 | 177 | 185 | 192 | 200 | 207 | 213 | 220 | 226 | 233 | 239 | 245 | 250 | 256 | 261 | 267 | 292 |
| 12 | 96 | 111 | 125 | 136 | 147 | 158 | 167 | 176 | 185 | 193 | 201 | 209 | 216 | 223 | 230 | 237 | 243 | 249 | 255 | 261 | 267 | 273 | 279 | 305 |
| 13 | 100 | 116 | 130 | 140 | 153 | 164 | 174 | 183 | 192 | 201 | 209 | 217 | 225 | 232 | 239 | 246 | 253 | 259 | 266 | 272 | 278 | 284 | 290 | 318 |
| 14 | 104 | 120 | 135 | 147 | 159 | 170 | 181 | 190 | 200 | 209 | 217 | 225 | 233 | 241 | 248 | 255 | 262 | 269 | 276 | 282 | 289 | 295 | 301 | 330 |
| 15 | 108 | 125 | 139 | 153 | 165 | 176 | 187 | 197 | 207 | 216 | 225 | 233 | 241 | 249 | 257 | 264 | 272 | 279 | 286 | 292 | 299 | 305 | 312 | 341 |
| 16 | 111 | 129 | 144 | 158 | 170 | 182 | 193 | 204 | 213 | 223 | 232 | 241 | 249 | 257 | 265 | 273 | 281 | 288 | 295 | 302 | 309 | 315 | 322 | 353 |
| 17 | 115 | 133 | 148 | 162 | 176 | 188 | 199 | 210 | 220 | 230 | 239 | 248 | 257 | 265 | 274 | 282 | 289 | 297 | 304 | 311 | 318 | 325 | 332 | 363 |
| 18 | 118 | 136 | 153 | 167 | 181 | 193 | 205 | 216 | 226 | 237 | 246 | 255 | 264 | 273 | 282 | 290 | 29- | 305 | 313 | 320 | 327 | 335 | 342 | 374 |
| 19 | 121 | 140 | 157 | 172 | 186 | 198 | 210 | 222 | 233 | 243 | 253 | 262 | 272 | 281 | 289 | 298 | 306 | 314 | 321 | 329 | 336 | 344 | 351 | 384 |
| 20 | 125 | 144 | 161 | 176 | 190 | 204 | 216 | 228 | 239 | 249 | 259 | 269 | 279 | 288 | 297 | 305 | 314 | 322 | 330 | 338 | 345 | 353 | 360 | 304 |
| 21 | 128 | 147 | 165 | 181 | 195 | 209 | 221 | 233 | 245 | 255 | 266 | 276 | 286 | 295 | 304 | 313 | 321 | 330 | 338 | 346 | 354 | 361 | 369 | 404 |
| 22 | 131 | 151 | 169 | 185 | 200 | 214 | 226 | 239 | 250 | 261 | 272 | 282 | 292 | 302 | 311 | 320 | 329 | 338 | 346 | 354 | 362 | 370 | 378 | 414 |
| 23 | 134 | 154 | 173 | 189 | 204 | 218 | 232 | 244 | 256 | 267 | 278 | 289 | 299 | 309 | 318 | 327 | 336 | 345 | 354 | 362 | 370 | 378 | 386 | 423 |
| 24 | 136 | 158 | 176 | 193 | 209 | 223 | 237 | 249 | 261 | 273 | 284 | 295 | 305 | 315 | 325 | 335 | 344 | 353 | 361 | 370 | 378 | 386 | 394 | 432 |
| 25 | 139 | 161 | 180 | 197 | 213 | 227 | 241 | 254 | 267 | 279 | 290 | 301 | 312 | 322 | 332 | 342 | 351 | 360 | 369 | 378 | 386 | 394 | 402 | 441 |
| 26 | 142 | 164 | 183 | 201 | 217 | 232 | 246 | 259 | 272 | 284 | 296 | 307 | 318 | 328 | 338 | 348 | 358 | 367 | 376 | 385 | 394 | 402 | 410 | 450 |
| 27 | 145 | 167 | 187 | 205 | 221 | 237 | 251 | 264 | 277 | 290 | 302 | 313 | 324 | 335 | 345 | 355 | 365 | 374 | 383 | 392 | 401 | 410 | 418 | 458 |
| 28 | 147 | 170 | 190 | 207 | 225 | 241 | 255 | 269 | 282 | 295 | 307 | 319 | 330 | 341 | 351 | 361 | 371 | 381 | 390 | 399 | 408 | 417 | 426 | 467 |
| 29 | 150 | 173 | 194 | 212 | 229 | 245 | 260 | 274 | 287 | 300 | 312 | 324 | 335 | 347 | 357 | 368 | 378 | 388 | 397 | 407 | 416 | 425 | 433 | 475 |
| 30 | 153 | 176 | 197 | 216 | 233 | 249 | 264 | 279 | 292 | 305 | 318 | 330 | 341 | 353 | 363 | 374 | 384 | 394 | 404 | 414 | 423 | 432 | 441 | 483 |
| 31 | 155 | 179 | 200 | 219 | 237 | 253 | 269 | 283 | 297 | 310 | 323 | 335 | 347 | 358 | 369 | 380 | 391 | 401 | 411 | 420 | 430 | 439 | 448 | 491 |
| 32 | 158 | 182 | 204 | 223 | 241 | 257 | 273 | 288 | 302 | 315 | 328 | 341 | 353 | 364 | 375 | 386 | 397 | 407 | 417 | 427 | 437 | 446 | 455 | 499 |
| 33 | 160 | 185 | 207 | 226 | 245 | 261 | 277 | 292 | 307 | 320 | 333 | 346 | 358 | 370 | 381 | 392 | 403 | 414 | 424 | 434 | 443 | 453 | 462 | 506 |
| 34 | 162 | 188 | 210 | 230 | 248 | 265 | 282 | 297 | 311 | 325 | 338 | 351 | 363 | 375 | 387 | 398 | 409 | 420 | 430 | 440 | 450 | 460 | 469 | 514 |
| 35 | 165 | 190 | 213 | 233 | 252 | 269 | 286 | 301 | 316 | 330 | 343 | 356 | 369 | 381 | 393 | 404 | 415 | 426 | 436 | 447 | 457 | 467 | 476 | 522 |
| 36 | 167 | 193 | 216 | 236 | 255 | 273 | 290 | 305 | 320 | 334 | 348 | 361 | 374 | 386 | 398 | 410 | 421 | 432 | 442 | 453 | 463 | 473 | 483 | 529 |
| 37 | 170 | 196 | 219 | 240 | 259 | 277 | 294 | 310 | 325 | 339 | 353 | 366 | 379 | 392 | 404 | 415 | 427 | 438 | 448 | 459 | 470 | 480 | 490 | 536 |
| 38 | 172 | 198 | 222 | 243 | 262 | 281 | 298 | 314 | 329 | 344 | 358 | 371 | 384 | 397 | 409 | 421 | 432 | 444 | 454 | 465 | 476 | 486 | 496 | 543 |
| 39 | 174 | 201 | 225 | 246 | 266 | 284 | 302 | 318 | 333 | 348 | 362 | 376 | 389 | 402 | 414 | 426 | 438 | 450 | 461 | 471 | 482 | 492 | 503 | 551 |
| 40 | 176 | 204 | 228 | 249 | 269 | 288 | 305 | 322 | 338 | 353 | 367 | 381 | 394 | 407 | 420 | 432 | 444 | 455 | 467 | 477 | 488 | 499 | 509 | 558 |
| 45 | 187 | 216 | 241 | 264 | 286 | 305 | 324 | 341 | 358 | 374 | 389 | 404 | 418 | 432 | 445 | 458 | 471 | 483 | 495 | 506 | 518 | 529 | 540 | 591 |
| 50 | 197 | 228 | 254 | 279 | 301 | 322 | 341 | 360 | 377 | 394 | 401 | 426 | 441 | 455 | 469 | 483 | 496 | 509 | 522 | 534 | 546 | 558 | 569 | 623 |
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 30 |

To use the table, determine the height of the warm column of air from the point of entrance to the point of discharge. Ascertain the difference between its temperature and that of the external air. Take out number from table, and multiply by the section-area of the discharge-tube or opening, in foot or decimals of a foot. The result is the discharge in cubic feet per minute, multiply by 60—result, discharge per hour. *Example.*—Height of column, 32 feet; difference of temperature between internal and external air, 17 deg. Looking in the table, we find opposite to 32 and under 17, 375 feet. That would be an area of 1 square foot.

But supposing our air opening to be only ¾ of a foot, we must multiply 375 by ¾ or 0·75 of a foot.

```
 375
 ·75
─────
1875
2625
─────
281·25
```

Therefore we get 281 feet (pe minute), multiplied by 60 = 16,860 feet per hour.

If the movement of the external air influences the movement in the room, as when the wind blows through openings, calculation is useless, and the anemometer only can be depended on.

## SECTION III.

## EXAMINATION OF THE AIR.

### 1. BY THE SENSES.

Many impurities are quite imperceptible to smell, but it so happens that animal organic matters, whether arising in respiration or in disease, have, for the most part, a peculiar fœtid smell, which is very perceptible to those trained to observe it when they enter a room from the open air. This is, in fact, a most delicate, as well as a ready way of detecting such fœtid impurities, and, with a little trouble, the sense of smell may be cultivated to the point of extreme acuteness. Only, it must be remembered, that in a short time the impression is lost, and is not at once regained even in the open air. For a detailed consideration of this question see Dr de Chaumont's papers in the "Proceedings of the Royal Society," 1875 and 1876. Among other points, it is shown that the humidity of the air has a very marked influence in rendering the smell of organic matter perceptible, even more powerful than a rise in temperature. Thus the effect of an increase of *one per cent.* in the humidity is as great as a rise of 4°·18 Fahr. in temperature, calculated from the mean of 458 fully recorded observations.*

As the evidence of the senses, however practically useful, is always liable to be challenged, a more thorough examination of the air must in many cases be made.

### 2. MICROSCOPICAL AND CHEMICAL EXAMINATION.

The points which should be examined are—†

1. The existence and character of suspended matters as judged of by the microscope.
2. The amount of carbonic acid, which is taken as a convenient measure of all impurities.
3. The amount of the ammonia existing as such, or formed by the action of alkaline permanganate on nitrogenous substances floating in the air (free and albuminoid ammonia).
4. The amount of oxidisable substances, as judged of by the amount of oxygen given off by permanganate.
5. The amount of watery vapour.
6. The presence of sulphuretted hydrogen, or of ammonia.

### *Microscopical Examination.*

1. *Suspended Matters.*‡—It is probable that the microscopical examination of air will give us in future more important information even than the chemical examination. It is, of course, a merely qualitative test, as there are no means of properly estimating the amount collected.

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* Supplementary Note on the Theory of Ventilation, Proceedings of the Royal Society, Nov. 171-1876.

† The amounts of oxygen and nitrogen can also be determined; but very numerous observations have shown that the oxygen often varies within extremely narrow limits, even when there is no doubt of the presence of considerable impurity in the air, so that as far as present knowledge gives, the determination of its amount is no good guide as a general rule.

‡ See page 97 for an account of the suspended matters in air.

The suspended matters may be collected very simply by Pouchet's aeroscope. A small funnel is drawn into a small point, below which is a slip of glass moistened with glycerine. The end of the funnel and a slip of glass are inclosed in an air-tight chamber, from which a small glass tube passes out and is connected by india-rubber tubing with an aspirator. As the water runs out through the aspirator, air passes down the funnel and impinges on the glycerine, which arrests any solid particles.

As it is, however, desirable to avoid glycerine, which may (in spite of previous careful examination) contain foreign particles, a still better plan is, to take a small bent tube, wash it thoroughly, dry it, and heat it to redness; when cool, it should be placed in a freezing mixture, an india-rubber tube be fixed on one end, and air slowly drawn through; the water of the air condenses in the tube, and many of the solid particles fall with it. A drop is then taken by a perfectly clean glass rod, previously heated to redness, placed on a clean glass, and looked at with an immersion lens, as soon after collection as possible.

Or air may be drawn through pure distilled water, a drop of which is then examined.

Dr Watson (Staff-Surgeon), in his examination of the air at Netley,[*] used fine glass threads soaked in pure glycerine, or dry, and crushed glass; after the air was drawn through, he washed the glass threads with pure water, and then examined the water. These glass threads form good traps for the larger particles.[†]

An aspirator, to draw air through the tubes, is very easily made; a square tin vessel, with a tap below, and a small opening above to receive the india-rubber tube, is all that is necessary; fill this with water, and let it run down, and measure the total quantity (in a pint vessel) discharged without tilting the vessel. An imperial pint contains 34·659 cubic inches, and one fluid ounce 1·733 cubic inches. A cubic foot is very nearly 1000 fluid ouuces, and the ounce may be taken as 1·728 cubic inches.[‡] The exact delivery of the aspirator is, therefore, easily determined; the air should be drawn slowly through the bent tube in the freezing mixture or through the aeroscope, so that no particles can escape.

### *Chemical Examination.*

2. *Estimation of Carbonic Acid.*—For our purpose the method proposed by Pettenkofer is the best. A glass vessel is taken capable of holding a gallon, or 4½ litres. The capacity is determined by filling it with water, and by measuring the contents by means of a litre or pint measure (1 oz. = 28·4 cubic centimeters). The vessel is thoroughly dried, and is then filled with the air to be examined, which is most readily done by pumping in the air with a bellows. Angus Smith recommends extracting the air from the bottle. When this is done 60 C.C. of clear lime or baryta water are put in, and the mouth is closed with an india-rubber cap.[§] The vessel is agitated, so that the lime water may run over the sides, and then is left to stand for not less than six or eight hours if lime-water be used; if baryta-water be used the experiment may be completed in a much shorter time, less than one hour.

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[*] Army Medical Department Report, vol. xi. p. 529.

[†] I have found carrying the air through a succession of bottles containing pure distilled water the best plan, for the sediment is examined by the microscope, and the liquid part can be used for chemical examinations for organic matter. (F. de C.)

[‡] These numbers are exact at 39° Fahr., or the maximum density point of water.

[§] Should an india-rubber cap not be available, a cork or a bung may be used, tied over with leather or oil-skin; in that case the second alkalinity of the lime-water (if this be used) should be determined as soon after the six or eight hours as possible, certainly within 24 hours.

The carbonic acid is absorbed by the lime or baryta water, and consequently the causticity of these fluids is, *pro tanto*, lessened. If the causticity of the lime or baryta is known before and after it has been placed in the vessel, the difference will give the amount of lime or baryta which has become united with carbonic acid.

The causticity of lime is determined by means of a solution of crystallised oxalic acid. If 2·25 grammes of crystallised $\bar{O}$ ($\bar{O}$ + 3Aq) are dissolved in 1 litre of water, 1 C.C. will exactly neutralise 1 milligramme (·001 gramme) of lime; 30 C.C. of lime water are taken, and exactly neutralised; good turmeric paper is the best plan for determining the exact point of neutralisation, and the margin of the drop gives the most delicate indication. The amount of lime in the 30 C.C. is then equal to the number of C.C. of oxalic acid used; it is always somewhere between 34 and 41 milligrammes.*

After the lime has absorbed the carbonic acid of the air in the vessel, 30 C.C. of the solution are taken out and tested with the oxalic acid solution as before; the difference shows the milligrammes of lime precipitated by the $CO_2$. Multiply the difference by 0·795, the result is the C.C. of $CO_2$ in the quantity of air examined. Deduct 60 C.C. from the total capacity of the jar (to account for the space occupied by the lime water put in), and state the capacity in litres and decimals: divide the C.C. of $CO_2$ obtained by the corrected capacity of the jar; the quotient is the C.C. of $CO_2$ per 1000 volumes of air.

*Example.*—The first alkalinity of lime-water was, . . . . . . 39· for 30 C.C.
After exposure to the air in the jar it was, . . . . 33· „
Difference, being milligrammes of lime, . . . . . . 6· precipitated by $CO_2$ in jar.
Multiply by factor, . . . 0·795

4·770 = Total $CO_2$ in jar in CC

Capacity of jar, . . . . . . . 4385 C.C.
Deduct 60 CC. for space taken by lime-water, 60

Net capacity, . . . . . . = 4325 C.C. = 4·325 litres.
Then 4·770 ÷ 4·325 = 1·103 C.C. of $CO_2$ per litre, or volumes per 1000.

The factor 0·795 is obtained as follows:—The difference between the two alkalinities expresses milligrammes of lime precipitated by carbonic acid; from this the milligrammes of $CO_2$ can be got, by calculating from the ratios of the equivalents thus:

$$\begin{array}{ccccccccc} \text{CaO.} & & \text{CO}_2. & & \text{Mgm. of CaO.} & & \text{Mgm. of CO}_2. & & \\ 56 & : & 44 & :: & a & : & x & : \therefore & x = a \times \frac{44}{56}. \end{array}$$

As one C.C. of $CO_2$ at 32° Fahr. (0°. cent.) weighs 1·9767 milligrammes, the ratio between weight and volume is $\frac{1}{1·9767} = 0·506$; $\therefore x \times 0·506 =$ C.C. of $CO_2$, corresponding to the milligrammes by weight. As 60 C.C. of lime-water were put into the jar, and only 30 C.C. taken, the result must be multiplied by 2. Therefore the factors combined are: $\frac{44}{56} \times 0{\cdot}506 \times 2 = 0{\cdot}795$, and this, multiplied by $a$, the difference between the two alkalinities, gives $x$, the total C.C. of $CO_2$ in the jar.

---

* The amount varies with the temperature, lime being less soluble in hot than cold water, at 60·7 the amount is 38·6 with a difference of +0·1 for every degree below that, and −0·1 for every degree above (Fahr.).

If baryta be used instead of lime, it must be free of traces of potash and soda; a much smaller quantity of liquid may be employed, as it is so much more soluble than lime; the calculation is the same.

A correction for the temperature of the air examined must be made, the standard being 32° Fahr., or the freezing-point of water. If the temperature be above this (as it will generally be, at least in buildings) the air will be expanded, and a smaller quantity, consequently, will be operated on. On the other hand, below 32° the air will be contracted, and a larger quantity operated on than at the standard temperature. This can be corrected by adding 0·2 per cent. to the result for every degree above 32°, and subtracting it for every degree below; the reason being that air expands or contracts 0·2 per cent. for every degree (or 1 per cent. for every 5 degrees) it deviates from the standard. (See METEOROLOGY.)

*Example.*—In the preceding example the $CO_2$ was found to be 1·103 per 1000. Suppose the temperature to have been 60° Fahr., then $60 - 32 = 28°$ to be corrected for; $28 \times 0{\cdot}2 = 5{\cdot}6$ per cent. to be added on to result, or the result must be multiplied by 1·056, $\therefore 1{\cdot}103 \times 1{\cdot}056 = 1{\cdot}154$ per 1000, the corrected result. Suppose the temperature had been 25° Fahr., then $32 - 25 = 7°$ to be corrected for; $7 \times 0{\cdot}2 = 1{\cdot}4$ per cent. to be deducted, or the result must be multiplied by $1{\cdot}00 - {\cdot}014 = 0{\cdot}986$, $\therefore 1{\cdot}103 \times 0{\cdot}986 = 1{\cdot}087$, the corrected result.

A correction for pressure is not necessary, unless the place of observation be much removed from sea-level; in that case, the barometer must be observed, and a rule of three stated.

$$\left.\begin{array}{l}\text{As standard height of bar:}\\ (=29{\cdot}92\text{ in.}=760\text{ mm.}):\end{array}\right\}\left\{\begin{array}{c}\text{observed height}\\ \text{of bar:}\end{array}\right\} :: \text{capacity} : x.$$

3. *Estimation of Free Ammonia and of the Nitrogenous Matter in Air by conversion into Albuminoid Ammonia.*—The nitrogenous matter existing in air may be in the form of dead or living matter of very various kinds. Its determination may be useful as showing that one or other of these classes of substances exists in the air in proportions greater than in pure air. The amount of nitrogen may be estimated in a similar manner to that proposed by Wanklyn and Chapman for water. The late Mr Chapman,* finding that water did not sufficiently absorb the nitrogenous substances in air, proposed to heat finely-powdered pumice-stone to redness, to moisten it with pure water, and then to place it over some coarse pieces of pumice-stone supported on wire in a funnel; a definite quantity of air (say 100 litres) is then drawn through the funnel; the pumice-stone is transferred to a retort containing water freed from ammonia, and distilled as in the determination of the albuminoid ammonia of water. (See page 83.) Dr Angus Smith† takes a bottle of about 2000 C.C. capacity, places in it 30–50 C.C. of the purest water, draws into it the air to be examined, and then agitates the water in the bottle, and proceeds as in Wanklyn's and Chapman's water test. The most convenient way is to draw the air through a succession of wash bottles, each containing 100 C.C. of water, perfectly free from ammonia, by a measured aspirator, and then to determine the free and albuminoid $NH_3$ in Wanklyn's method.

Another plan is to lead a definite quantity of air through a clean curved tube, surrounded by a freezing mixture; the water of the air condenses, and with it much of the organic matter; the tube is then washed out with pure water, the washings are put into a retort with ammonia-free water, and distilled as usual. After passing through the tube the air should be led through pure water to arrest the portion of organic matter that always escapes condensation.

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* Chemical News, Feb. 11, 1870.

† Air and Rain, p. 421.

The amount of ammonia (free and albuminoid) is determined as in water analysis. The mere presence of free ammonia may be determined by exposing strips of filtering paper, dipped in Nessler's solution or in the etherial solution of the alcoholic extract of logwood: the former becomes yellow, the latter purple.

The quantity of air drawn through must, of course, be accurately determined by a properly arranged aspirator, and the results then calculated in milligrammes per cubic metre.*

4. *Estimation of the Oxidisable Matters in the Air in terms of Oxygen.*—In this case a definite quantity of air is drawn through a solution of permanganate of potassium of known strength, and the amount of undecomposed permanganate is determined by oxalic acid. Or part of the water through which the air has been drawn for the ammonia determinations may be examined in the same way as in the case of drinking water. The permanganate acts upon various matters in the air, besides the putrescible organic matters, such as sulphuretted hydrogen, nitrous acid, tarry matters, &c. The presence or absence of $H_2S$ may be determined qualitatively by means of acetate of lead papers, ammonium sulphide by paper dipped in nitroprusside of sodium; whilst tarry matters would generally be recognised by the smell of the water, or its turbidity. In the absence of these the difference between the permanganate determinations, before and after boiling with sulphuric acid, may be calculated as nitrous acid, as in the case of drinking water; whilst the result after boiling may be reckoned as the oxygen for oxidisable organic matter only.†

The nitric acid may also be determined, in the same way as in drinking water, from the washings of the air obtained as above.

All these determinations should be made, when opportunities offer, as the results may prove hereafter of some value.

5. *Watery Vapour.*—The hygrometric condition of the air is known in various ways, especially by the dry and wet bulbs, as explained in the chapter on METEOROLOGY. The hair hygrometer is a very useful instrument for this purpose, as it marks the degree of humidity much more quickly than the dry and wet bulbs.

## SECTION IV.

## SCHEME FOR THE APPLICATION OF THE FOREGOING RULES.

When a ventilation inquiry is about to be made, everything ought to be got ready before-hand. A number of bottles (about 4 to 4½ litres), or glass jars, ought to be carefully measured, and the capacity in C.C. (less 60 C.C. to account for the lime-water) marked upon them; each bottle ought also to have a closely fitting india-rubber cap and a distinctive number. These bottles are to be used for collecting the samples of air for $CO_2$. Charges of lime-water (each 60 C.C.) ought to be carefully measured off with a burette, or graduated pipette, into small stoppered bottles. Two or more sets of wet and dry bulb thermometers ought to be ready, and two or more series of not less than six bottles, each containing about 100 C.C. of pure distilled water, connected together with glass tubes and india-rubber caps; also four or more aspirators* for drawing the air through the bottles. One of Casella's small air meters, with a long pole in joints, into which it can be screwed, a measuring tape and foot rule, a pair of bellows, a pocket compass, some pieces of cotton-velvet, a note-book, are also necessary.

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* One cubic metre equals 1000 litres, or 1,000,000 CC.

† See Reports on St Mary's Hospital by Dr. F. de Chaumont.

When a room has to be examined, enter it after being some time in the open air, and notice if there be any smell; record the sensation at once in your notes. Hang up the wet and dry bulb thermometer (if it has not been placed there before), and then proceed to take samples of the air for $CO_2$; if necessary, attach a piece of india-rubber tubing to the nozzle of the bellows, so as to get down to the bottom of the jar. Pump about 50 or 100 strokes; then pour in the lime-water from one of the small bottles, put on the india-rubber cap, and shake it up. Always take *two* samples at least, and more if a large room. Note the numbers of the bottles. Take the wet and dry bulb readings. Arrange the set of bottles with distilled water in some convenient place, and attach them to one of the aspirators, which may be allowed to flow into another below it. When the upper one is empty it may be changed for the lower one, and so the stream of air may be carried on for any length of time, as seems necessary,—the number of times the aspirators are changed should be duly noted. In determining the carbonic acid, put out all the lights, or have only sufficient for working purposes; allow no smoking, and have no person in the room but those who are sleeping there. The aspirators may be allowed to go on continuously, but the examination of the air for $CO_2$ ought to be repeated at intervals, the exact time of observations being noted. At the same time, similar observations ought to be made in the open air, as nearly as possible simultaneously with those inside. At some convenient time the measurements of the room and the ventilators, the velocities of the currents of air, &c., should be taken on some such plan as the following:—Measure the cubic space, then consider the possible sources of entrance and exit of air; if there are only doors and windows, notice the distance between them, how they open, on what external place they open; whether there is free passage of air from side to side; whether it is likely the air will be properly distributed. On all these points an opinion is soon arrived at. If there are other openings, measure them all carefully, so as to get their superficies; the chimney must be measured at its throat or smallest part. Determine then the direction of movement of air through these openings by smoke, noting the apparent rapidity. The doors and windows should be closed. When the inlets have been discovered, consider whether the air is drawn from a pure external source, and whether there is proper distribution in the room. Then measure the amount of movement in both inlets and outlets with the anemometer, or calculate by the table if it seems safe to do so.

If the ventilation of the room is influenced by the wind, the horizontal movement of the external air should be determined by Robinson's anemometer, or the little air-meter by Casella may be also used for this purpose.

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* The aspirator is simply a tin box of about one cubic foot (28½ litres) in capacity, it is filled with water and there is a short tube in the top, to which the tube from the bottle may be connected by means of an india-rubber cap. At the bottom there is a tap by which the water can be drawn off; as the vessel empties an equivalent bulk of air enters, having passed through the bottles. Each time an aspirator is emptied the quantity of air drawn through should be noted; the velocity of the current ought not to be too great, and it can be easily regulated by the tap. It is well to number the aspirators and mark the capacity on each, as in the case of the bottles.

In recording the velocity of the air at any openings, it is convenient to mark an incoming current with a *plus* sign and an outgoing with a *minus*, thus: + 75 would mean an incoming current at the rate of 75 feet per minute; whilst − 63 would mean an outgoing current at 63 feet per minute.

When the final analyses are made, and the amount of $CO_2$ determined, the amount of air per head per hour, supplied and utilised, ought to be calculated out (as before explained), and compared with the amount of movement determined with the air meter. If the quantities accord fairly, the distribution may be considered good; on the other hand, if they differ, an excess by the air-meter shows bad distribution, whilst a deficiency indicates some other source of incoming air not yet observed.

The water, through which the air has been passed by the aspirator, ought to be examined at once, if practicable; if not, the bottles ought to be carefully stoppered, and the stoppers tied down with leather or strong linen,—when convenient, the sediment should be examined microscopically, and the water (when the sediment has subsided) chemically as before explained.

# CHAPTER V.

# FOOD.

## SECTION I.

### GENERAL PRINCIPLES OF DIET.

A food is either a substance with a store of potential or latent energy, which is capable of being manifested in the body under the form of heat, electricity, mechanical movement, formative power (if such a term may be used), &c., and which manifestations serve the purposes of healthy life,* or it is a substance which aids or permits the manifestation and application of this energy. Under the first head come all the substances capable of oxidation (or deoxidation, or splitting, if it be hereafter proved that energy is manifested or transformed during such alterations); and under the second, the substances which, though not oxidisable, play an essential part in preparing the conditions for chemical changes, such as water and some salts. Neither class, *per se*, is capable of the manifestation of energy, and therefore the title of food is strictly applicable only when both classes are present. Indeed, it may be said that the full powers as food, even of the first class, are only manifested when certain different kinds of aliments which make up the class exist together. There must, therefore, be a combination of the so-called foods to maintain perfect nutrition. The enumeration and classification of the foods or aliments necessary to maintain human life in its most perfect state have been usually based on the deduction of Prout, that milk contains all the necessary aliments, and in the best form. The substances in milk are—1st, the nitrogenous matters, viz., the casein principally, and in smaller quantities, albumen, lacto-protein, and perhaps other albuminous bodies; 2d, the fat and oil; 3d, sugar in the form of lactin; 4th, water and salts, the latter being especially combinations of magnesium, calcium, potassium, sodium, and iron, with chlorine, phosphoric acid, and in smaller quantities sulphuric acid.

In addition to their occurrence in milk, which is admitted to be a perfect food for the young, this enumeration of aliments appears to be justified by two considerations. First, that the different members of each class, *inter se*, have a remarkably similar composition, while there are broad lines of physical and chemical demarcation between the classes; and secondly, that the different classes appear to serve different purposes in nutrition, and are all necessary for perfect health.

The first point is obvious enough. The nitrogenous aliments are blood-fibrine, muscle-fibrine or syntonin, myosin, vegetable fibrine, albumen in its various forms, casein (in its animal and vegetable forms), and globulin. Their composition, &c., is remarkably uniform; they contain between 15·4 and 16·5 per cent. of nitrogen, and may be conveniently distinguished by the common term of albuminates. They can replace each other in nutrition. There are some other nitrogenous bodies, such as gelatine and chondrin, and the substances classed under keratin or elastin, which, though approaching in chemical characters to the other substances, are not their nutritive equals.

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* The addition that the manifestation of energy in the body serves the purposes of healthy nutrition is necessary to distinguish the actions of food from those of medicines or poisons, which only serve healthy nutrition indirectly by acting on the processes of unhealthy nutrition.

The second class consists of the various animal and vegetable fats, wax, &c., the composition of which is very uniform, and the chief nutritive differences of which depend on physical conditions of form or aggregation, which cause some fats, when acted upon by the alimentary fluids, to be more easily absorbed than others.

The group of the starchy and saccharine substances (the carbo-hydrates), or of their allies or derivatives (dextrin, pectin), is equally well characterised by chemical resemblances, *inter se*, and differences from the other groups. The several dietetic starches, sugars, including lactin, cellulose (whose want of nutritive power is dependent on form and aggregation, and which requires for digestion a more elaborate apparatus than some animals possess), and the various derivatives of the starches, are all closely allied. There has been some doubt whether pectin should be classed chemically with the sugar and starch group, as the oxygen and hydrogen are not in the proportions to form water, but this is perhaps no objection to its association in a dietetic classification.

The fourth class, consisting of the salts already noted and of water, needs no comment.

The physiological evidence that these classes of aliments serve different purposes in nutrition is not so complete as that of their chemical differences.

Few will doubt, I persume, that a broad distinction must be drawn between the nitrogenous and non-nitrogenous substances. Late researches, which have much modified our opinion of the direction in which the potential energy of the dietetic principles may be manifested (as heat, or electricity, or mechanical movement), and of the mode in which the nitrogenous substances in particular, aid or restrain this transformation, do not, it appears to me, impeach the proposition that the presence of nitrogen in an organised structure, and its participation in the action going on there, is a necessary condition for the manifestation of any force, or any chemical change. Whether, when energy is manifested, the nitrogenous framework of any nitrogenous structure is a mere stage on which other actors play, or whether it is used up and destroyed, or is, on the other hand, built up or renovated during action, is, as far as classification of food is concerned, a matter of no consequence.

The following considerations seem to prove the necessary participation of the nitrogenous structures in manifestations of energy. Every structure in the body in which any form of energy is manifested (heat, mechanical motion, chemical or electrical action, &c.) is nitrogenous. The nerves, the muscles, the gland cells, the floating cells in the various liquids, the semen and the ovarian cells, are all nitrogenous. Even the non-cellular liquids passing out into the alimentary canal at various points, which have so great an action in preparing the food in different ways, are not only nitrogenous, but the constancy of this implies the necessity of the nitrogen, in order that these actions shall be performed; and the same constancy of the presence of nitrogen, when function is performed, is apparently traceable through the whole world. Surely such constancy proves necessity. Then, if the nitrogen be cut off from the body, the various functions languish. This does not occur at once, for every body contains a store of nitrogen, but it is at length inevitable. Again, if it is wished to increase the manifestation of the energies of the various organs, more nitrogen must be supplied. The experiments of Pettenkofer and Voit show that the nitrogenous substances composing the textures of the body determine the absorption of oxygen.[*] *The condensation of the oxygen from the atmosphere, its conversion into its active condition (ozone), and its application to oxidation, are according to their experiments entirely under the control of the nitrogenous tissues (fixed and floating), and are apparently proportional to their size and vigour,*[†] *and to changes occurring in them.* The absorption of oxygen does not determine the changes in the tissues, but the changes in the tissues determine the absorption of oxygen. In other words, without the participation of the nitrogenous bodies, no oxidation and no manifestation of energy is possible. If I rightly interpret the experiments, they show that the absorption of oxygen by the lungs (blood-composition, and physical conditions of pressure, &c., remaining constant), is dependent on its disposal in the body, and that this disposal is in direct relation with the absolute and relative amount and action of the nitrogenous structures. Mechanical motion, electricity, or heat may be owing to oxidation of fat or of starch, or of nitrogenous substance; but whatever be the final source, the direction is given by the nitrogenous structures.

The next point is not quite so clear. Are the non-nitrogenous bodies, the fats and the starches, to be again broadly separated into two groups, which cannot replace each other; or, are these nutritively convertible? It is now certain that fat arises from albuminates,[‡] so that the nitrogenous substance plays two parts—first, of the organic framework, *i.e.*, of the regulator of oxidation and of transformation of energy; and second, it forms a non-nitrogenous substance which is oxidised and transformed.

The experiments of Edward Smith, Fick and Wislicenus, Haughton, and others, on muscular action, prove that we must look for the main source of energy which is apparent during muscular action in the oxidation of non-nitrogenous substances, but no experiments have yet shown whether these are fatty or saccharine. It seems to be inferred that it is fat which is thus chiefly acted upon; but this opinion is rather derived from a reference to the universal presence of fat when energy is manifested, to the known necessity of it in diet (for though the dog and the rat (Savory) can live on fat-free meat alone, man cannot do so),[§] and from the large amount of energy its oxidation can produce, than from actual observation. If it were true, a broad distinction would be at once drawn between fatty and starchy food, but it is not experimentally proved. If, on the other hand, it were certain that the starchy aliments formed fat in the human body as a rule, this would be a reason for drawing no distinction between the groups. Independent of the argument drawn from bees fed on sugar alone and forming wax, from the fattening of ducks and geese, and the older experiments on pigs, the later experiments of Lawes and Gilbert[||] seem to clearly show that the fat stored up in fattened pigs cannot be derived from the fat given in the food, but must have been produced partly from nitrogenous substances, but chiefly from the carbohydrates. So also it seems now probable that the fat in milk is not derived at once from blood, but from changes of albumen in the lacteal gland-cells. There seems no reason why we should not extend the inference to man. If so, a man could live in perfect health on a diet composed only of fat-free meat and starch, with salts and water, just as he can certainly live (though perhaps not in the highest health) on meat, fat, salts, and water. The carbo-hydrates would then be proved to be able to replace fats. The experiment has not yet been performed to my knowledge, but it seems important it should be.

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[*] Zeitsch. für Biologie, band ii. p. 457. See especially the summary of their opinion at page 571.

[†] When to a diet of meat, which causes a certain absorption of oxygen, fat or sugar is added, the absorption of oxygen lessens (Ranke, Phys. des Menschen, 1868, p. 145); so that it is relative as well as absolute amount which comes into play.

[‡] According to Hennebey, 100 parts of dry albumen can yield 51·4 parts of fat.

[§] Ranke could not maintain himself in perfect nutrition on meat alone. Physiol. des Menschen 1868, p. 149.

[||] On the Sources of the Fat in the Animal Body, Phil. Mag. Dec. 1866.

Grouven's experiments also suggest that in cattle the carbo-hydrates may split up in the alimentary canal into glycerine, lactic, and butyric acids, and carbonic acid and marsh gas. If this be true, in the herbivora the starches would be merely another form of fat.

An argument against the fats and carbo-hydrates being mutually replaceable under ordinary conditions in the diet of men is drawn from a consideration of the diets used by all nations. In no case in which it can be obtained is an admixture of starch, in some form, with fat omitted. Moreover, in all cases (except in those nations, like the Esquimaux, who are under particular conditions of food) we find that the amount of fat taken is comparatively small as compared with that of starches. Why should this be, if the two groups serve virtually the same end? Is it a matter of chance that nature has everywhere mixed up fat and carbo-hydrates in those foods on which men thrive best, or is it this mixture which has aided in making men what they are? Analyse almost all the known diets in the world, which are not, so to speak, diets of necessity, and they consist (besides water and salts) of nitrogenous substances, fat, and starches. If the two latter are convertible, why should we not find in some places diets of albuminates and fats only; in others of albuminates and starches only? Why should there be this singular uniformity of combination? Why, also, should all nations so eagerly seek after starches and sugars, even when fats are available, so that it seems almost an instinct to desire them? The fats when taken into the body enter like the albuminates into the structure of the tissues,* of which fat forms in probably all cases an essential part. The carbo-hydrates, on the other hand, in the human body do not appear to be parts of the tissues, though they are contained in the fluids which bathe them, or are contained in them. The special direction which the chemical changes in the carbo-hydrates take in the body, seem also to point to special duties. Thus, the formation of lactic and other acids of the same class must arise from carbo-hydrates chiefly or solely. But the formation of these acids is certainly most important in nutrition, for the various reaction of the fluids, which offer so striking a contrast (the alkalinity of the blood, the acidity of most mucous secretions, of the sweat, urine, &c.), must be chiefly owing to the action of lactic acid on the phosphates, or the chlorides, and to the ease with which it is oxidised and removed. If the direction of the changes which the carbo-hydrates undergo within the body is different from that of the fats, the products of these changes must be inferred to play dissimilar parts.

Without pushing these arguments too far, and with the admission that the subject is very obscure, I think we are entitled to assert that the two groups of fats and carbo-hydrates are not so immediately and completely convertible as to permit us to place them together in a classification of diets.

In the second question to which reference was made, viz., that of a nitrogenous substance furnishing fat, or a carbo-hydrate, the case is simpler. The experiments of Voit, and of Lawes and Gilbert, as well as other considerations, prove that the fat of tissues may be derived from nitrogenous substances, and there are reasons to believe that a glycogenous substance may also be derived from albuminates.* It is also probable, though not proved, that these non-nitrogenous derivatives may be burnt up in the muscles and other parts, as Fick conjectures.† But this cannot allow us to consider an albuminate as an aliment which may replace fat or starch in the case of man. The digestive system of man is framed so differently from that of the carnivora, that fat must be taken in its own form, for it either cannot be formed in sufficient quantity from albuminates, or the body is poisoned by the excess of nitrogen which is necessarily absorbed to supply it.

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* The fats appear to pass into the body directly and after saponification, which renders absorption easy. The soap is then, according to Radziejewski's experiments (Virchow's Archiv, band xliii. p. 268), reconverted into fat. It has been supposed that the greater part o the tissue fat (fat cells) is not derived in this way, but from the tissue albuminates; but Hofmann's experiments and reasonings (Zeitsch. für Biol., band viii, p. 153.) seem to show that the ingested fats are stored up largely. Clinical observations certainly support this view.

With regard to the necessity of all four classes of aliments, it can be affirmed with certainty, that (putting scurvy out of the question) men can live for some time and be healthy with a diet of albuminates, fat, salts, and water. But special conditions of life, such as great exercise, or exposure to very low temperature, appear to be necessary, and under usual conditions of life health is not very perfectly maintained on such diet. It has not yet been shown that men can live in good health on albuminates, carbo-hydrates, salts, and water, &c., without fat.‡

The exact effect produced by the deprivation of any one of these classes is not yet known. An excess of the albuminates causes a more rapid oxidation of fat (and in dogs an elimination of water), while an excess of fat lessens the absorption of oxygen, and hinders the metamorphosis of both fat and albuminate tissues. The carbo-hydrates have the same effect when in excess, and appear to lessen the oxidation of the two other classes.

It is now generally admitted that the success of Mr Banting's treatment of obesity is owing to two actions: the increased oxidising effect on fat, consequent on the increase of meat (especially if exercise be combined), and the lessened interference with the oxidation of fat consequent on the deprivation of the starches.

Health cannot be maintained on albuminates, salts, and water alone; but, on the other hand, it cannot be maintained without them.

The salts and water are as essential as the nitrogenous substances. *Lime*, chiefly in the form of phosphate, is absent from no tissue; and there is reason to think no cell growth can go on without it; certainly in enlarging morbid growths and in rapidly growing cells it is in large amount.

When phosphate of calcium was excluded from the diet, the bones of an adult goat were not found by H. Weiske to be poorer in lime,§ because probably lime was drawn from other parts; but the goat became weak and dull, so that nutrition was interfered with. The lowest forms of life (Bacteria and Fungi) will not grow without earthy phosphates.

Magnesia is probably also an essential constituent of growth in some tissues. Potash and soda, in the forms of phosphates and chlorides, are equally important, and would seem to be especially concerned in the molecular currents; forming parts of almost all tissues, they are less fixed, so to speak, than the magnesian and lime salts. It is also now certain, that the two alkalies do not replace each other, and have a different distribution; and it is so far observable, that the potash seems to be the alkali for the formed tissues, such as the blood cells or muscular fibre; while the soda salts are more largely contained in the intercellular fluids which bathe or encircle the tissues.

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* In addition to physiological evidence from experiments on animals, there are certain forms of diabetes which seem to prove that sugar must be formed either from albuminates or fat, most probably the former.

† Archiv. für ges. Phys. band v. p. 40.

‡ In some experiments I have made both with Liebig's essence of meat and Hassall's dried food with bread, I was very much struck with the bad effect produced on the health of the experimentators, and with the immediate relief given by the addition of butter and a larger supply of starch, without augmentation in the amount of nitrogen.

§ Zeits. für Biol. band. vii. p. 179.

The chlorine and phosphoric acid have also very peculiar properties,—the former apparently being easily set free, and then giving a very strong acid, which has a special action on albuminates, and the latter having remarkable combining proportions with alkalies. Both are furnished in almost all food; the sodium chloride also separately. Carbonic acid is both introduced and made in the system, and probably serves many uses. Iron is, of course, also essential for certain tissues or parts, especially for the red-blood corpuscles, and for the colouring matter in muscle, and in small quantity is found almost in every tissue, and in every food. The sulphur and phosphorus of the tissues appear to enter especially as such with the albuminates.

Some salts, especially those which form carbonates in the system, such as the lactates, tartrates, citrates, and acetates, give the alkalinity to the system which seems so necessary to the integrity of the molecular currents. The state of malnutrition, which in its highest degree we call scurvy, appears to follow inevitably on their absence; and as they exist chiefly in fresh vegetables, it is a well-known rule of dietetics to supply these with great care though their nutritive power otherwise is small. So important are those substances, that they might well be placed in a separate class, although Dr Pavy remarks that "these principles are hardly of sufficient importance, in an alimentary point of view, so called, for their consideration under a distinct head." Surely, this is an under-estimate of their importance, considering the inevitable malnutrition that follows on their absence.

In addition to the substances composing these four classes, there are others which enter into many diets, and which have been termed "accessory foods," or by some writers "force regulators" (like the salts). The various condiments which give taste to food, or excite salivary or alimentary secretions, and tea, coffee, cocoa, alcohol, &c., furnish the chief substances of this class. Much discussion has taken place as to the exact action in nutrition of these substances, but little is definitely known. They may possibly undergo chemical action (oxidation or splitting), or, without doing so, may enter into combination with gland cells or tissues, and modify the currents or molecular movements, and thus be entitled to the term of "force regulators," but it is impossible at present to assign to them their true action.

I have entered so far into this subject chiefly for the purpose of showing why I believe the old classification of aliments to be correct, and why, whatever may be the future direction of physiology, it is not likely to be seriously affected.

Admitting the necessity of a certain amount of each of the four classes for a perfect diet, it has now to be inquired what quantity of each class is necessary, and how the latent energy in each class may be best secured for the purposes of the body.

## SUB-SECTION I.—QUANTITY OF EACH CLASS OF PROXIMATE ALIMENT IN A GOOD DIET FOR HEALTHY MEN.

This has been determined partly by observation on a great number of dietaries, and partly by physiological experiments. The general result of the whole are given in the following table:—

*Standard diet* [*] *for a Male European Adult, of average height (5 ft. 6 in. to 5 ft. 10 in.) and average weight = 140 lbs. av. (66 kilogrammes) to 160 lbs. )72·7 kilogrammes), in moderate work.*

| Water-free Substances given Daily. | Ounces Avoir. | Grammes. |
|---|---|---|
| Albuminous substances, . . . . | 4·587 | 130 |
| Fatty substances, . . . . . . | 2·964 | 84 |
| Carbo-hydrates, . . . . . . | 14·257 | 404 |
| Salts, . . . . . . . . . . | 1·058 | 30 |
| Total water-free food, . . | 22·866 | 648 |

Assuming the water-free food to be 23 ounces, and a man's weight to be 150 lb, each lb weight of the body receives in 24 hours 0·15 ounces, or the whole body receives nearly $\frac{1}{100}$ part of its own weight.

This is the dry food, but a certain amount of water (between 50 and 60 per cent. usually), is contained in it, and adding this to the water-free solids, the total daily amount of so-called dry food (exclusive of liquids) is about 40 ounces. In addition to this, from 50 to 80 ounces of water are taken in some liquid form, making a total supply of water of 70 to 90 ounces, or on an average 0·5 ounces for each lb weight of body.

This average amount of food and water varies considerably, from the following causes:—

1. Individual conditions of size, vigour, activity of circulation, and of the eliminating organs, &c. No men eat exactly the same, and no single standard will meet all cases.[*] The usual average range in different male adults is from 34 to 46 ounces of so-called solid food, and from 50 to 80 ounces of water.

2. Differences of exertion. If men are undergoing great exertion they take more food, and, if they can obtain it, the increase is especially in the classes of albuminates and fat.

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[*] I have copied this table from Moleschott. The numbers are generally received, and are fairly accordant with the observations of numerous other writers. Pettenkofer and Voit give the following (Zeits. für Biol. band ii. p. 523) as the calculation for soldiers:—

| | | |
|---|---|---|
| Dry albuminous substances, . . . . . | 148 grammes | = 5·22 ounces. |
| Fat, . . . . . . . . . . . . | 103 „ | = 3·63 „ |
| Carbo-hydrates, . . . . . . . . | 378 „ | = 13·3 „ |

This gives rather more albuminates and fat and less starch than Moleschott's table. In the experiments with two healthy men in their experimental-room, the amount was, albuminates 137 grammes; fat, 117 grammes; and carbo-hydrates, 352 grammes daily. Ranke, however gives rather lower numbers—viz., 100 grammes of albuminates, 100 of fat, and 240 of starch (Phys. des Mem. 1868 p. 158), for moderate work.

[†] This has been well exemplified in our convict prisons, in which, as a matter of convenience, soldiers are sometimes confined. The ordinary diet, which is sufficient for the convict, is insufficient for the soldier, and that for several reasons: 1. The convict is a smaller man on the average; 2. The previous life of the convict is an irregular one, in which his food is generally insufficient, whereas the soldier's life is usually the opposite, his food is fairly good and his meals regular. 3. The crimes for which the convict is imprisoned are crimes against society, and his removal to a prison cannot be considered much of a degradation morally, whereas his physical condition is really improved. On the other hand the soldier's crime is often one of a military character only, hence his removal to a prison is a moral degradation: especially if it be a convict prison. The result is, that, whilst the majority of the civil prisoners retain their weight or even gain, the majority of soldier prisoners lose. It is also found that age has an effect, the older men losing, the younger generally gaining. Length of sentence has also an influence, partly on account of some difference of diet and work, but probably chiefly on account of the system ultimately accommodating itself to the altered conditions. Thus the men who lose weight are, the heaviest originally, the oldest, those with shortest sentences; those who are stationary or gain weight are, the lightest originally, the youngest, those with longest sentences. For the data, from which the above conclusions are drawn, I am indebted to Surgeon-major J. G. Marston, M.D. (F. DE C.)

*Average Daily Water-free Diet required for an adult Man in very laborious or of a Soldier on Service and in the Field.*

| | Ounces avoir. | | |
|---|---|---|---|
| Albuminates, | 6 | to | 7 |
| Fats, | 3·5 | to | 4·5 |
| Carbo-hydrates, | 16 | to | 18 |
| Salts, | 1·2 | to | 1·5 |
| Total water-free food, | 26·7 | to | 31·0 |

The amount of water is increased, but is very various according to circumstances, and is not so much augmented apparently as the solid food. On the other hand, men in rest will usually eat less; at any rate, the weight and health of the body can be maintained on less.

*The Average Daily Diet of Men in Quietude.*

| | Rest. | Subsistence diet (Playfair)† *i.e.*, sufficient for the internal mechanical work of the body. |
|---|---|---|
| Albuminates, | 2·5 | 2 |
| Fats, | 1 | ·5 |
| Carbo-hydrates, | 12 | 12 |
| Salts, | ·5 | ·5 |
| Total water-free food, | 16·0 | 15·0 |

The subsistence diet, though it will keep a man alive, will probably not prevent him from losing weight, and therefore is not really sufficient.

In convict prisons, Dr Wilson tells us that the men on light labour receive 224 grains of nitrogen and 4651 grains of carbon, and this is sufficient. Those on hard labour receive 255 grains of nitrogen and 5289 grains of carbon, and on this diet they lose weight, and have to be continuously shifted from heavy to lighter work. In the case of military prisoners at hard labour even 282 grains of nitrogen and 5373 grains of carbon were insufficient to prevent men losing weight.‡ In India an improved diet was introduced by the late Surgeon-General Beatson, in which the nitrogen was about 300 grains and the carbon about 5300. This appears to have been sufficient to prevent loss of weight, although there was a deficiency of fat.

3. Differences of climate. It is a matter of general belief that more food is taken in cold seasons and in cold countries than in hot. It is supposed that more energy in some form (finally in that of heat) is necessary, and more food is required: but there may be other causes, such as varying exertion.

In the case of any diet the articles of which are known, the amounts of the four classes of alimentary principles may be calculated from a table of mean composition. The following table is compiled from, in most cases, several analyses by different authors, those analyses being selected which seem best to represent the food of the soldier.*

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* Playfair gives the diet of a prize-fighter in training as 9·8 oz. albuminates, 3·1 fats, and 3·27 starch and sugar. There were 690 grains of nitrogen, and 4366 grains of carbon.

† The amount of two ounces of albuminates is that fixed by Playfair (Food of Man in relation to his useful Work) as furnishing by calculation the amount of force sufficient to carry on the internal work of the body. Although our views are now somewhat modified on this point, I believe the numbers express pretty accurately the actual food which will keep a man alive,

‡ Recently changes have been introduced, but hardly for the better, it is to be feared.

Whenever practicable, the nutritive value should be calculated on the raw substance, as the analyses of cooked food are more variable. It must then be seen that no loss occurs in cooking.

The mode of using the table is very simple; the quantity of uncooked meat or bread being known, and it being assumed or proved that there is no loss in cooking, a rule-of-three brings out at once the proportions. Thus, the ration allowance of meat for soldiers being 12 oz., 2·4 oz. or 20 per cent. is deducted for bone, as the soldier does not get the best parts. The quantity of water in the remaining 9·6 ounces will be $\frac{75 \times 9{\cdot}6}{100} = 7{\cdot}2$, and the water-free solids will be 2·4 ounces. The albuminates will be 1·44 ounce; the fats, ·8064; and the salts, ·1536 ounce.

In the case of salt beef or pork, it is not certain how the value should be calculated. The analysis by Girardin † gives for uncooked salt beef (American)—

| | | |
|---|---|---|
| 49·11 | per cent. | of water, |
| 24·82 | „ | fibrin and cellular tissue, |
| 3·28 | „ | extractive matters, |
| ·70 | „ | albumen, |
| ·18 | „ | fat, |
| 21·07 | „ | soluble salts; |

but the analysis of the brine shows that much of the nutritious matters, organic and mineral (phosphoric acid, lactic acid, magnesia), have passed out of the meat. ‡ Liebig has reckoned the nutritive loss at one-third, or even one-half. It appears from Kühne's observations, that myosin is soluble in a 10 per cent. solution of chloride of sodium, and hence a large quantity of this substance necessarily passes into the brine. Analyses show, it is true, a large percentage of fibrin and cellular tissue, in salt meat, but this is made up of indigestible nitrogenous substances, which afford, probably, little real nutritive material. Perhaps salt beef may be reckoned as equal to two-thirds the quantity of fresh beef; this estimate is certainly quite high enough. §

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* Of course such tables are merely approximative; but they are very useful as giving a general idea of a diet, although they are not accurate enough to be used in physiological inquiries.

† Comptes Rendus, xli. 756.

‡ Liebig found that the brine is saturated with the juice of meat, and Mr Whitelaw (*Chemical News*, March 1864) has shown, that extract of meat may be obtained by dialysis from the brine.

§ In the accompanying table several articles have been added which are likely to come within the diet of soldiers or sailors, either on duty or in hospital, such as salt beef and pork, bacon, white fish, poultry, cream, skimmed milk, and pemmican.

The *Cooked Meat* given in the table may be taken as fairly representing the soldier's ration meat, not counting bone.

Among the articles not included in the table are some of the preserved meats recently introduced, particularly the *Compressed Corned Beef*, prepared by the Wilson Packing Company of Chicago,—which is likely to be used as a field ration for our army, both during war and in manœuvres in time of peace. It is excellent meat, very palatable and highly nutritious, being ready cooked and in a very convenient form for carriage on the march. It is stated to be equal to more than double the quantity of uncooked meat, and this is fully borne out by analysis, as it contains about 60 per cent. of solid matter, of which about 40 are albuminates, 15 fat, and 5 salts;—the nitrogen is over 6 per cent. Half a pound would form an ample ration for the field, with the due proportion of bread or biscuit, &c. As it is merely *corned*, and not *salted* like ordinary salt meat, it is probable that its constituents may be allowed their full nutritive value.

## *Table for Calculating Diets.*

| Articles. | In 100 Parts. | | | | |
|---|---|---|---|---|---|
| | Water. | Albuminates. | Fats. | Carbohydrates. | Salts. |
| Meat of best quality, with little fat, like beefsteaks, | 74·4 | 20·5 | 3·5 | ... | 1·6 |
| Uncooked meat of the kind supplied to soldiers,—beef and mutton. Bone constitutes ⅕th of the soldier's allowance,* | 75 | 15 | 8·4 | ... | 1·6 |
| Uncooked meat of fattened cattle. Calculated from Lawes' and Gilbert's experiments. These numbers are to be used if the meat is very fat, | 63 | 14 | 19 | ... | 3·7 |
| Cooked meat,† roast, no dripping being lost. Boiled assumed to be the same, | 54 | 27·6 | 15·45 | ... | 2·95 |
| Salt beef (Girardin), | 49·1 | 29·6 | 0·2 | ... | 21·1 |
| ,, pork (Girardin), | 44·1 | 26·1 | 7·0 | ... | 22·8 |
| Fat pork (Letheby), | 39·0 | 9·8 | 48·9 | ... | 2·3 |
| Dried bacon (Letheby), | 15·0 | 8·8 | 73·3 | ... | 2·9 |
| White fish (Letheby), | 78·0 | 18·1 | 2·9 | ... | 1·0 |
| Poultry (Letheby), | 74·0 | 21·0 | 3·8 | ... | 1·2 |
| Bread, white wheaten, of average quality, | 40 | 8 | 1·5 | 49·2 | 1·3 |
| Wheat flour, average quality, | 15 | 11 | 2 | 70·3 | 1·7 |
| Biscuit, | 8 | 15·6 | 1·3 | 73·4 | 1·7 |
| Rice, | 10 | 5 | ·8 | 83·2 | 0·5 |
| Oatmeal (Letheby),‡ | 15 | 12·6 | 5·6 | 63·0 | 3 |
| Maize (Poggiale), | 13·5 | 10 | 6·7 | 64·5§ | 1·4 |
| Peas (dry), | 15 | 22 | 2 | 53§ | 2·4 |
| Potatoes,‖ | 74 | 1·5 | ·1 | 23·4 | 1 |
| Carrots (cellulose excluded),‖ | 85 | ·6 | ·25 | 8·4 | ·7 |
| Cabbage,‖ | 91 | ·2 | ·5 | 5·8 | ·7 |
| Butter, | 6 | ·3 | 91 | ... | variable. taken as 2·7 |
| Egg (10 per cent. must be deducted for shell from the weight of the egg), | 73·5 | 13·5 | 11·6 | ... | 1 |
| Cheese, | 36·8 | 33·5 | 24·3 | ... | 5·4 |
| Milk (sp. gr. 1030 and over),¶ | 86·7 | 4 | 3·7 | 5 | ·6 |
| ,, (sp. gr. 1026), | 90 | 3 | 2·5 | 3·9 | ·5 |
| Cream (Letheby), | 66 | 2·7 | 26·7 | 2·8 | 1·8 |
| Skimmed milk (Letheby), | 88 | 4·0 | 1·8 | 5·4 | 0·8 |
| Sugar, | 3 | ... | ... | 96·5 | ·5 |
| Pemmican (de Chaumont)** | 7·2 | 35·4 | 55·2 | ... | 1·8 |

The precise amount of the mineral matters of the various articles can be calculated when necessary, from the analysis given under the head of each article.

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* The gelatine of the meat is reckoned with the albuminates: it is not certain what deduction hould be made on account of its lower nutritive value, which is about ¼th that of albumen 3ischof).

† These numbers are taken from John Ranke's analysis.

‡ I have determined the nitrogen in good Scotch oatmeal, and the results are almost identi-al with Letheby's. I have therefore omitted Von Bibra's analysis given in the 3d edition.

§ There is also some indigestible cellulose in maize, peas, and carrots, which is not included n the table.

‖ Professor Attfield (Report of Committee on Scurvy, 1877, p. xlv. *et seq.*) gives rather different igures, reckoning the albuminates a good deal higher.

¶ These numbers are probably rather high.

** The sweet pemmican used in the Arctic Expedition of 1875-6 was similar to the above the ordinary pemmican used in the same Expedition) with the addition of about 5 per cent. f cane sugar. In other cases, particularly in the American pemmican, raisins and currants re added. (See Report of Committee on Scurvy for analyses by Professor Frankland and r de Chaumont). A little pepper is added, not reckoned quantitatively in the above nalysis, but probably included in the "loss," *i.e.*, the difference between the sum of the bove constituents and 100.

The proportion of the nitrogenous substances to the fats and carbo-hydrates are in the standard diet as follows:—

| | |
|---|---|
| Albuminates, . . . | 1 |
| Fat, . . . . . . | ·6 nearly. |
| Carbo-hydrates, . . . | 3 |

This is as 1 of nitrogenous to 3·6 of non-nitrogenous; but as is often done, if 1 part of fat be reckoned as equal to 2·4 parts of starch, the proportion will be 1 of dry nitrogenous to (·6 × 2·4) + 3), 4½ nearly of dry non-nitrogenous or carboniferous substances, taken as starch.

*Amount of Nitrogen and Carbon.*—As the phenomena of nutrition are chiefly owing to the various chemical interchanges of nitrogen and carbon, and in some cases of hydrogen, with oxygen, it may be desired to calculate the amount of nitrogen and carbon in any diet. This may be done in two ways.

1. Calculate out the dry albuminates, fat, and carbo-hydrates in ounces, and then use the following table.

| Nitrogen and Carbon in grains. | Nitrogen. | Carbon. |
|---|---|---|
| 1 ounce of water-free albuminate, | 69 | 233* |
| 1 ounce of water-free fat, . . | ... | 345·6 |
| 1 ounce of water-free carbo-hydrate (except lactin), | | 194·2† |

If the diet be largely of milk, the amount of lactin (milk carbo-hydrate) must be determined; 1 ounce of lactin contains 175 grains of carbon.

2. In the following table, the calculation of these ingredients per ounce has been made; the substance being supposed to be in its natural state, and to have the composition already assigned to it in the former table.

| Substance. | One ounce (= 437·5 grains) contains in its natural state in grains. | | | |
|---|---|---|---|---|
| | Water. | Nitrogen. | Carbon. | Salts. |
| Uncooked meat (beef), . . | 328 | 10·35 | 64 | 7 |
| Uncooked fat meat (beef), . . | 275·6 | 9·6 | 98·3 | 16 |
| Cooked meat, . . . . . | 236 | 19 | 117·7 | 13 |
| Salt beef, . . . . . . | 215 | 20·4 | 69·7 | 92·3 |
| ,, pork, . . . . . . | 192 | 18·0 | 85·0 | 99·7 |
| Fat pork, . . . . . . | 170 | 6·8 | 192·0 | 10·1 |
| Dried Bacon, . . . . . | 65·6 | 6·1 | 273·8 | 12·7 |
| White fish, . . . . . | 341 | 11·5 | 52·4 | 4·4 |
| Poultry, . . . . . . | 324 | 14·5 | 62·0 | 5·2 |
| Bread, . . . . . . | 175 | 5·5 | 119 | 5·6 |
| Wheat flour, . . . . . | 65·6 | 7·6 | 169 | 7·4 |
| Biscuit, . . . . . . | 35 | 22·7 | 183 | 7·4 |
| Rice, . . . . . . . | 43·7 | 3·5 | 176 | 2·2 |
| Oatmeal, . . . . . . | 65·6 | 8·7 | 172 | 13 |
| Maize, . . . . . . | 59 | 7 | 176 | 6 |
| Peas, . . . . . . . | 65·6 | 15 | 161 | 10 |
| Potatoes, . . . . . . | 324 | 1 | 49 | 4·4 |
| Carrots, . . . . . . | 398 | ·4 | 18 | 3 |
| Butter, . . . . . . | 26 | ·2 | 315 | 11·8 |
| Egg, . . . . . . . | 321 | 9·3 | 71·5 | 4·4 |
| Cheese, . . . . . . | 161 | 23 | 162 | 23·6 |
| Milk, . . . . . . . | 380 | 2·75 | 30·8 | 2·6 |
| Cream, . . . . . . | 289 | 1·9 | 93·5 | 7·9 |
| Skimmed Milk, . . . . . | 385 | 2·8 | 25·0 | 3·5 |
| Sugar, . . . . . . | 13 | ... | 187 | 2 |
| Pemmican, . . . . . | 31 | 24·3 | 273·5 | 8·0 |

---

* After deducting the carbon of urea, the number is 208.

† These numbers are thus obtained: the various dry albuminates contain from 15·4 to 16·4

Some additions must be made to this table. I found the steak used for the patients at Netley to contain as much as 14·22 grains of nitrogen per ounce,* and this number should be used for the best hospital steaks and chops. Hospital bread contains only 3·6 grains of nitrogen in each ounce of crumb, and 4·78 in each ounce of crust.†

The standard daily diet for an adult man, calculated in this way, gives—

| | |
|---|---|
| Nitrogen, . . . . . . | 316·5 grains, |
| Carbon, . . . . . . | 4862 „ |
| Salts, . . . . . . . | 461 „ |

Not infrequently the standard is stated as 20 grammes of nitrogen, and 300 grammes of carbon; this is equal to 308·6 and 4629 grains.

The usual range is from 250 to 350 grains of nitrogen for adult men, and the extreme range is from 2 to 7 ounces of dry albuminate, or from 138 grains of nitrogen (which is the smallest amount necessary for the inner movements of the body, and the bare maintenance of life, as calculated by Playfair), to 483 or 500 grains, which is the amount taken under very great exertion. Edward Smith's careful observations on ill fed and fairly fed operatives, give a range of from 135 grains of nitrogen and 3271 grains of carbon (in London needlewomen) to 349 grains of nitrogen and 6195 grains of carbon (in Irish farm labourers). Usually, however, in what are almost starvation diets, the nitrogen is 180 to 200 grains, and the carbon from 3900 to 4300 grains (Edward Smith's investigations into the food in Lancashire during the cotton famine). The carbon ranges in various diets, from 3600 to 5800 or 6000 grains. The amount of the salts (461) appears rather large; it is difficult to test it by determining the salts in the excreta, as so much sodium chloride

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per cent. of nitrogen. I have selected 15.8 for the range for European diet, as it represents the nitrogen of syntonin; there is also 53·5 per cent. of carbon; fat contains 79 per cent., starch and sugar 44·4 and lactin 40 per cent. of carbon. I have not taken into account any hydrogen in excess of that forming water with the oxygen of the food. If this be calculated from the fat it will give a mean of about 48 grains per ounce, in the albuminates about 8·6; albuminates also contain about 8 grains of sulphur.

* Some discussion has lately taken place with regard to the amount of nitrogen in meat nearly free from fat. Voit has stated the mean amount at 3·4 per cent. Huppert (Zeitsch. für Biologie, band vii. p. 354) estimates it at 3·3. Petersen (Ibid. p. 166) makes the mean numbers 3·29 per cent. in fat-free beef; 3·25 in pork; 3·15 in mutton; 3·18 in veal; and 3·4 in horse. In beafsteak (fat-free nearly) I found it to be 3·25. Huppert's numbers seem to be nearest the truth.

It has been stated by Toldt and Nowak that combustion with soda-lime does not give all the nitrogen in meat, and that Dumas' oxide of copper analysis must be used. But Petersen's careful trials (Zeitsch. für Biologie, band vii. p. 166) do not confirm this; and the results of the two methods were extremely close, as the following experiments show:—

| | Per cent. of Nitrogen. | | | |
|---|---|---|---|---|
| | Soda-lime burning. | | Oxide of Copper. | |
| Beef (shoulder), . . | 3·35 | 3·36 | 3·41 | 3·35 |
| Beef (leg), . . . | 3·24 | 3·24 | 3·29 | 3·30 |

And as Fresenius found the oxide of copper gave slightly too high results (·2 to ·5 per cent.), the difference should be still less. In some later experiments, published by Seegen and Nowak (Zeitsch für die ges. Phys. band vii. p. 284), they found that the soda-lime always gave too little nitrogen, the error (as compared with the copper oxide) being as a mean about 1·5 per cent. Märcker (Archiv für die ges. Phys. band viii. p. 195, 1873) has since given evidence opposed to these results, and considers the soda-lime determination as much nearer the truth than Seegen and Nowak assert.

† My recent analyses give considerably higher amounts. See Reports on Hygiene, Army Med. Reports, vol. xviii. (F. de C.)

and lime salts are lost through the skin, and some of the excreted salts may also be mere surplusage. The salts seem to be made up of chlorine, 120 grains; phosphoric acid, 50 grains; potash, 40; soda, 40; lime, about 4 grains by the urine,* and some by the bowels; magnesia, 4·7 grains by the urine, and a considerable amount by the bowels; and iron, the amount of which is quite uncertain.

Actual experiment has, to a great extent, confirmed the conclusions drawn from a study of these dietaries. Pettenkofer and Voit, in two healthy men, determined many times the amount of nitrogen during common exercise, and found it to be 19·82 grammes, or 305·8 grains. I have experimented on four healthy average men in common work, and found the amount which kept them in perfect health and uniform weight was 293 to 305 grains of nitrogen in twenty-four hours. All these determinations are near Moleschott's numbers. The amount of carbon is, however, perhaps too large. In Ranke's careful experiments in a state of rest, there were consumed by a man 160·6 ℔ weight, 240 grains of nitrogen, and 3531 grains of carbon; as a rule, the later experiments show that the amount of carbon was put too high. A certain proportion between the carbon and nitrogen ought to be maintained; in the best diets this is: Nitrogen 1 to carbon 15.†

## Sub-Section II.—On the Energy Obtainable from the various Articles of Food.

The possible amount of energy which can be manifested in the body will be the result of two conditions; first, the amount of potential energy stored up in the food, which is, of course, easily determined and expressed in terms of units of heat or of motion; and second, the extent to which the processes in the body can liberate and apply this energy. For example, an ounce of albumen can give rise to a certain heating effect if it be burnt in oxygen; but in the body thorough oxidation can never occur, for some (about one-third) of the constituents of the albumen pass out incompletely oxidised in the form of urea. An ounce of sugar, on the other hand, is as a general rule destroyed to the fullest extent, and ends in carbonic acid and water, and its actual energy in the body, under whatever form it appears, is equal to its theoretical energy.

Tables have been given by chemists showing the amount of energy which may be manifested. The results have been obtained in some cases by calculation, and in others by direct experiment. In the following table I have selected Dr Frankland's experimental results as the most exact, but they agree very closely with the theoretical results, particularly with those given by Playfair‡ and others. Thus Playfair calculated that one ounce of dry albumen would give rise by oxidation to heat sufficient to raise 126·5 kilogrammes of water 1° cent., or to lift 173 tons 1 foot high,§ while Frankland's experimental number is almost identical—viz., 168·68 tons, lifted a foot.

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* I have followed Byasson in this and in the amount of magnesia in the urine, as his experiments appear carefully done.—*L'Activité Cérébrale et la Composition des Urines*, par le Dr H. Byasson, Paris, 1868, p. 43.

† The Soldier's Ration, by F. de Chaumont, Sanitary Record, Feb. 5, 1876.

‡ On the Food of Man in relation to his useful Work. 1865.

§ For an explanation of this term, see the chapter on Exercise.

*Energy developed by One Gramme or One Ounce of the following Substances when oxidised in the Body :—*

| Name of Substance. | Per cent. of Water. | One gramme will equal kilogrammetres of energy. | One ounce will equal foot-tons of energy, or, in other words, would raise the undergiven number of tons 1 foot high.* |
|---|---|---|---|
| Beef (lean), | 70·5 | 604 | 55 |
| Veal (lean), | 70·9 | 496 | 45·3 |
| Ham (lean, boiled), | 54·4 | 711 | 64·9 |
| **Salt beef, | 49·1 | 569 | 52 |
| ** ,, pork, | 44·1 | 751 | 69 |
| **Fat pork, | 39·0 | 2200 | 201 |
| **Dried bacon, | 15·0 | 3195 | 291 |
| **White fish, | 78·0 | 470 | 43 |
| **Poultry, | 74·0 | 556 | 51 |
| Bread crumb,† | 44 | 910 | 83 |
| Flour, | ... | 1627 | 148·5 |
| Ground rice, | ... | 1591 | 145·3 |
| Oatmeal, | ... | 1665 | 152 |
| Pea meal, | ... | 1598 | 146 |
| Potatoes, | 73 | 422 | 38·5 |
| Carrots, | 86 | 220 | 20 |
| Cabbage, | 88·5 | 178 | 16·2 |
| Butter, | ... | 3077 | 280·9 |
| Egg (white of), | 86·3 | 244 | 22·3 |
| Egg (yolk), | 47 | 1400 | 127 |
| Cheshire cheese, | 24 | 1846 | 168·5 |
| Arrowroot, | ... | 1657 | 151·3 |
| Milk, | 87 | 266 | 24·3 |
| **Cream, | 66·0 | 1045 | 96 |
| **Skimmed milk, | 88·0 | 213 | 19·6 |
| Sugar (lump), | ... | 1418 | 129·5 |
| **Pemmican, | 7·2 | 3000 | 275 |
| Ale (Bass' bottled), | 88·4 | 328 | 30 |
| Porter (Guinness' Stout), | 88·4 | 455 | 41·5 |

A table of this kind is useful in showing what can be obtained from our food, but it must not be supposed that the value of food is in exact relation to the possible energy which it can furnish. In order that the energy shall be obtained, the food must not only be digested and taken into the body properly prepared, but its energy must be developed at the place and in the manner proper for nutrition. The mere expression of potential energy cannot fix dietetic value, which may be dependent on conditions in the body unknown to us. For example, it is quite certain, from observation, that

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[*] The first and second columns except those marked **, which are calculated from the analyses, are taken from Dr Frankland's paper in the Philos. Mag., Sept. 1866, p. 196. The third column is calculated from the second, by multiplying by 28·35 (the number of grammes in an ounce avoirdupois), and then by ·003229 to bring metre-kilo-grammes into foot-tons, or directly by 0·091. The substances are not dried, but in their natural state.

| | | |
|---|---|---|
| One ounce of dry albuminate yields | 174 | foot-tons of potential energy. |
| ,, ,, fat, | 378 | ,, ,, |
| ,, ,, starch, | 135 | ,, ,, |
| ,, ,, cane-sugar, | 129 | ,, ,, |
| ,, ,, lactin or glucose, | 122 | ,, ,, |
| One grain of carbon (converted into $CO_2$), | 0·701 | ,, ,, |
| ,, hydrogen (water), | 3·000 | ,, ,, |
| ,, sulphur ($SO_2$), | 0·205 | ,, ,, |
| ,, phosphorus ($P_2O_5$), | 0·510 | ,, ,, |
| ,, carbon (forming urea), | 0·198 | ,, ,, |

[†] The crust of bread is very nearly double the amount.

gelatine cannot fully take the place of albumen, though its potential energy is little inferior,* and it is easily oxidised in the body. But owing to some circumstances, yet unknown, gelatine is chiefly destroyed in the blood (?) and gland cells, and its energy, therefore, has a different direction from that of albumen. So also of the potential energy, it is quite possible that all is not usefully employed. The tables of energy give broad indications, and can be used in a general statement of the value of a diet; but at present they do not throw light on the intricacies of nutrition.

### SUB-SECTION III.—ON THE RELATIVE VALUE OF FOOD OF THE SAME CLASS.

The chemical composition of animal and vegetable albuminates is very similar, and they manifestly serve equal purposes in the body. The meat-eater, and the man who lives on corn, or peas and rice, are equally well nourished. But it has been supposed that either the kind or the rapidity of nutrition is different, and that the man who feeds on meat, or the carnivorous animal, will be more active, and more able to exert a sudden violent effort, than the vegetarian, or the herbivorous animal, whose food has an equal potential energy, but which is supposed to be less easily evolved. The evidence in favour of this view seems to me very imperfect. The rapid movements of the carnivora have been contrasted with the slow, dull action of domestic cattle; but, not to speak of the horse, whoever has seen the lightning movements of the wild antelope or cow, or even of the wild pig, who is herbivorous in many cases, can doubt that vegetable feeders can exert a movement even more rapid and more enduring than the tiger or the wolf? And the evidence in men is the same: In India, the ill-fed people, on rice and a little millet or pea, may indeed show less power; but take the well-fed corn-eater, or even the well-fed rice and pea-eater, and he will show, when in training, no inferiority to the meat-eaters. An argument has been drawn from the complicated alimentary canal of the herbivora, but probably this is chiefly intended to digest the cellulose, and the digestion and absorption of albuminates may be as rapid as in other animals.

It appears from Dr Beaumont's experiments that animal food is digested sooner than farinaceous, and possibly meat might therefore replace more quickly the wasted nitrogenous tissue than bread or peas; and it may be true, as asserted, that the change of tissue is more quick in meat-eaters, who require, therefore, more frequent supplies of food. Even this, however, seems to me not yet thoroughly proved.

It has been also supposed that there is a difference in the nutrition of even such nearly-allied substances as wheat and barley, but the evidence is imperfect, and is perhaps dependent on differences in ease of digestion.

With respect to the fats, their differences of nutrition are probably dependent entirely on facility of digestion and absorption. The animal fats appear easier of absorption than the vegetable. Berthé† found that in addition to the fat in his ordinary diet, he could absorb 30 grammes, or 1·059 ounces of cod-liver oil, butter, or other animal oil; in some instances 1¾ ounces were absorbed. Of vegetable oils only 20 grammes, or 0·7 ounces, were absorbed. When, in experiments with cod-liver oil, 40 grammes were taken, 31·5 were absorbed, 8·5 passed by the bowels; when 60 grammes were taken, 48 were absorbed and 12 passed. But when he took 60 grammes daily, the amount of fat in the fæces gradually increased, until 50 grammes daily passed off in that way. In the dog, however, Bischoff and Voit found that 250 and 300 grammes (8·8 and 10·5 ounces) of butter were easily absorbed. During the digestion of the fats they are, probably, in part decomposed; and the fatty acids, like the acids derived from the starch, must, to a certain extent, antagonise the introduction of alkali in the food.

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* One gramme of dry isinglass will develop 4520 heat-units when burnt in oxygen; one gramme of dry boiled ham, 4343; one gramme of dry beef, 5313 heat-units. (Frankland, *op. cit.* p. 196.) The potential energy of isinglass is more than that of ham, but its nutritive power is far inferior.

† Ludwig's Phys. band ii. p. 668.

The various carbo-hydrates are generally supposed to be of equal value. Starch requires a little more preparation by the digestive fluids than grape sugar, into which it appears first to pass; but the change is so rapid that it can hardly be made a point of difference between them. It is observable, however, that even when sugar is very cheap and accessible, it is not used to entirely replace starch; but this, perhaps, may be a matter of taste.

## SUB-SECTION IV.—THE DIGESTIBILITY OF FOOD.

In order that food shall be digested and absorbed, two conditions are necessary; the food must be in a fit state to be digested, and it must meet in the alimentary canal with the chemical and physical conditions which can digest and absorb it.

Fitness for digestibility depends partly on the original nature of the substance, as to hardness and cohesion, or chemical nature, and partly on the manner in which it can be altered by cooking. Tables of degree of digestibility have been formed by several writers, and especially by Dr Beaumont, by direct experiment on Alexis St Martin; but it must be remembered that these are merely approximative, as it is so difficult to keep the conditions of cooking equal.*

Rice, tripe, whipped eggs, sago, tapioca, barley, boiled milk, raw eggs, lamb, parsnips, roasted and baked potatoes, and fricasseed chicken, are the most easily digested substances in the order here given,—the rice disappearing from the stomach in one hour, and the fricasseed chicken in 2¾ hours. Beef, pork, mutton, oysters, butter, bread, veal, boiled and roasted fowls, are rather less digestible,—roast beef disappearing from the stomach in three hours, and roast fowl in four hours. Salt beef and pork disappeared in 4¼ hours.†

As a rule, Beaumont found animal food digested sooner than farinaceous, and in proportion to its minuteness of division and tenderness of fibre.

The admixture of the different classes of food aids digestibility; thus fat taken with meat aids the digestion of the meat; some of the accessory foods probably increase the outpour of saliva, gastric or enteric juice, &c.

The degree of fineness and division of food; the amount of solidity and of trituration which should be left to the teeth, in order that the fluids of the mouth and salivary glands may flow out in due proportion; the bulk of the food which should be taken at once, are points seemingly slight, but of real importance. There is another matter which appears to affect digestibility, viz., variety of food.

According to the best writers on diet, it is not enough to give the proximate dietetic substances in proper amount. Variety must be introduced into the food, and different substances of the same class must be alternately employed. It may appear singular that this should be necessary; and certainly many men, and most animals, have perfect health on a very uniform diet. Yet, there appears no doubt of the good effect of variety, and its action is probably on primary digestion. Sameness cloys; and with variety, more food is taken, and a larger amount of nutriment is introduced. It is impossible, with rations, to introduce any great variety of food; but the same object appears to be secured by having a variety of cooking. In the case of children, especially, a great improvement in health takes place when variety of cooking is introduced; and by this plan (among others), Dr Balfour succeeded in marvellously improving the health of the boys in the Duke of York's School.

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* The preparation of food by cooking is so important a matter, that the art of cookery ought not to be considered as merely the domain of the gourmand. Health is greatly influenced by it, and it is really a subject to be practically studied by chemists and physiologists.

† An extended table is given in Cox's excellent edition of Combe's Physiology of Digestion p. 123.

The internal conditions of abundance and proper composition of the alimentary fluids, and the action of the muscular fibres in moving the food, so that it shall be submitted to them, depend on the perfection of the nervous currents, the vigour of circulation, and the composition of the blood. Many of the digestive diseases the physician has to treat depend on alterations in these conditions, so that the food is only imperfectly digested. Recent experiments, by Plôsz, Maly, and Gyergyai, seem to show the value of converting the albuminates into peptones by artificial digestion, so as to aid the digestion of the sick.*

## SECTION III.

## DISEASES CONNECTED WITH FOOD.

So great is the influence of food on health, that some writers have reduced hygiene almost to a branch of dietetics. Happiness, as well as health, is considered to be insured or imperilled by a good or improper diet, and high moral considerations are supposed to be involved in the due performance of digestion. If there is some exaggeration in this, there is much truth; and doubtless, of all the agencies which affect nutrition, this is the most important.

The diseases connected with food form, probably, the most numerous order which proceeds from a single class of causes; and so important are they, that a review of them is equivalent to a discussion on diseases of nutrition generally.

It is of course impossible to do more here than outline so large a topic.

Diseases may be produced by alterations (excess or deficiency) in quantity; by imperfect conditions of digestibility, and by special characters of quality.

### SUB-SECTION I.—ALTERATIONS IN QUANTITY.

1. *Excess of Food.*—In some cases, food is taken in such excess, that it is not absorbed; it then undergoes chemical changes in the alimentary canal, and at last putrefies; quantities of gas (carbonic acid, and carburetted and sulphuretted hydrogen) are formed. As much as 30 ℔ of a half-putrid mass have been got rid of by purgatives.† Dyspepsia, constipation, and irritation, causing diarrhœa, which does not always empty the bowels, are produced. Sometimes some of the putrid substances are absorbed, as there are signs of evident poisoning of the blood, a febrile condition, torpor and heavi-

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* Ueber Peptone, Archiv für die Ges. Phys. band ix. p. 323.

† A good case of this kind is recorded by Routh (Fæcal Fermentation, p. 19). Some convicts in Australia received from 7¼ to 7½ ℔ of food daily. Obstinate constipation, dyspepsia, diarrhœa, skin diseases, and ophthalmia were produced. Purgatives brought away large quantities of half-putrid masses.

ness, fætor of the breath, and sometimes possibly even jaundice. It was, no doubt, cases of this kind which led to the routine practice of giving purgatives; and as this condition, in a moderate degree, is not uncommon, the use of purgatives will probably never be discontinued.

The excess of food may be absorbed. The amount of absorption of the different alimentary principles is not precisely known. Dogs can digest an immense quantity of meat, and especially if they are fed often; and not simply largely, once or twice a-day. In men, also, much meat and albuminous matter can be digested,* though it is by no means uncommon, in large meat-eaters, to find much muscular fibre in the fæces. Still, enough can be taken, not merely to give a large excess of nitrogen, but even to supply carbon in sufficient quantity for the wants of the system.

There is certainly a limit to the digestion of starch (though sugar, however, is absorbed in large amount), as after a very large meal much starch passes unaltered. This is also the case with fat; and if large quantities are given, much passes by the bowels. But in all cases, habit probably much affects the degree of digestive power; and the continued use of certain articles of diet leads to an increased formation of the fluids which digest them.

When excess of albuminates continually passes into the system, congestions and enlargements of the liver, and probably other organs, and a general state of plethora, are produced. If exercise is not taken at the same time, there is a disproportion between the absorbed oxygen and the absorbed albuminates, which must lead to imperfect oxidation, and therefore to retention in the body of some substances, or to irritation of the eliminating organs by the passage through them of products less highly elaborated than those they are adapted to remove.

Although not completely proved, it is highly probable that gouty affections arise partly in this way, partly probably from the use of liquids which delay metamorphosis, and therefore lead to the same result as increased ingestion, and in some degree also from the use of indigestible articles of food.

Very often large meat-eaters are not gouty, and do not appear in any way over-fed. In this case either a great amount of exercise is taken, or, as is often the case in these persons, the meat is not absorbed, owing frequently to imperfect mastication.

A great excess of albuminates, without other food, produces, in a short time (five days—Hammond) marked febrile symptoms, malaise, and diarrhœa; and if persevered in, albumen appears in the urine. Ranke has attributed the depression especially to the effect of the salts of the meat.

Excess of starches and of fats delays the metamorphosis of the nitrogenous tissues and produces excess of fat. Sometimes acidity and flatulence are caused by the use of much starch. It is not understood if profounder diseases follow the excessive use of starches unless decided corpulence is produced, when the muscular fibres of the heart and of many voluntary muscles lessen in size, and the consequences of enfeebled heart's action are produced. When an excessive quantity of starch is used to replace albuminates, in physiological experiments, the condition becomes of course a complex one.

If an excess of starch be taken under any circumstances, much passes into the fæces, and the urine often becomes saccharine.

There may be also excess of food in a given time; that is, meals too frequently repeated, though the absolute quantity in twenty-four hours may not be too great.

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* Jones's and especially Hammond's experiments, Experimental Researches, 1857, p. 20.

2. *Deficiency of Food.*—The long catalogue of effects produced by famine is but too well known, and it is unnecessary to repeat it here. But the effects produced by deficiency in any one of the four great classes of aliments, the other classes, being in normal amount, have not yet been perfectly studied.

The complete deprivation of albuminates, without lessening of the other classes, produces marked effects only after some days. In a strong man kept only on fat and starch, I found full vigour preserved for five days; in a man in whom I reduced the amount of nitrogen one-half, full vigour was retained for seven days. If the abstention be prolonged, however, there is eventually great loss of muscular strength, often mental debility, some feverish and dyspeptic symptoms. Then follow anæmia and great prostration. The elimination of nitrogen in the form of urea greatly lessens, though it never ceases, while the uric acid diminishes in a less degree. If starch be largely supplied, the weight of the body does not lessen for seven or eight days (Hammond).

If the deprivation of albuminates be less complete (70 to 100 grains of nitrogen being given daily), the body gradually lessens in activity, and passes into more or less of an adynamic condition, which predisposes to the attacks of all the specific diseases (especially of malarious affections and typhus), and of pneumonia, and modifies the course of some of these diseases, as, for instance, of typhoid, which runs its course with less elevation of temperature than usual, and with less or with no excess of ureal excretion.

The deprivation of starches can be borne for a long time if fat be given, but if both fat and starch are excluded, though albuminates be supplied, illness is produced in a few days. Nor is it difficult to explain this: as albumen contains 53·5 per cent. of carbon and 15·5 per cent. of nitrogen, to supply 3500 grains of carbon no less than 1014 grains of nitrogen must be introduced, a quantity three times as great as the system can easily assimilate, unless enormous exertion be taken, and then the quantity of carbon becomes insufficient.

Men can be fed on meat for a long time, as a good deal of fat is then introduced, and if the meat be fresh (and raw?), scurvy is not readily induced.

The deprivation of fat does not appear to be well borne, even if starches be given; but the exact effects are not, I believe, known. The great remedial effects produced by giving fat in many of the diseases of obscure malnutrition, prove that the partial deprivation of fat is both more common and more serious than is supposed.* The deprivation of the salts is also evidently attended with marked results which are worthy of more attention than they have yet received.

Bad effects are also produced if the intervals between meals are too long; this is a matter in which there is great individual difference, and need not be further referred to.

## SUB-SECTION II.—CONDITIONS OF DIGESTIBILITY AND ASSIMILATION.

A great number of diseases are produced, not by alterations in quantity or by imperfections in quality of the raw food, but by conditions of indigestibility, either dependent on physical or chemical conditions of the food itself, or of the digestive fluids. To some persons certain foods are indigestible at all times, or at particular times. Indigestibility leads to retention, and then to the results of retention, viz., chemical changes and putrefaction going on in the stomach and bowels under the influence of warmth, moisture, and air. Then irritation is produced, and dyspepsia, diarrhœa, or dysentery, are caused.

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* In all the diets ordered for soldiers, prisoners, &c., the fat is greatly deficient in every country.

Indigestibility extends, however, farther than this. There is some reason for thinking that the albuminates sometimes pass into the circulation less properly prepared than usual to undergo the action of the liver, and that they therefore produce irritation of that organ, and passing into the blood in some unassimilable state, produce irritation of the skin or kidneys. Sometimes, indeed, albumen appears in the urine, as if it had circulated like a foreign body in the blood. Such conditions are usually allied to some evident error in primary digestion, but occasionally are not obviously accompanied by any gastric disorder. Whether there is any similar imperfection in the digestion of starch or fat is not at present known.

### SUB-SECTION III.—CONDITIONS OF QUALITY.

Altered quality of what is otherwise good food produces a great number of diseases. Most of these are referred to under the headings of the different articles of food, and the subject is merely introduced here to complete the general sketch of the production of disease from food.

In inquiring, then, into the effect of food, the following appears to be the best order of procedure:—

1. Is the food excessive or deficient in quantity as a whole or in any of the primary classes of aliments?
2. Are the different articles digestible and assimilable, or, from some cause inherent in the food or proper to the individual, is there difficulty in primary digestion or want of proper assimilation?
3. Is the quality of the food altered either before or after cooking?

# CHAPTER VI.

## QUALITY, CHOICE, AND COOKING OF FOOD, AND DISEASES ATTRIBUTABLE TO IMPROPER QUALITY.

### SECTION I.

### MEAT.

The advantages of meat as a diet are—its large amount of nitrogenous substance, the union of this with much fat, the presence of important salts (viz., chloride of potassium, phosphate, and carbonate of potassium, or a salt forming carbonate in incineration), and iron. It is also easily cooked, and is very digestible; it is probably more easily assimilated than any vegetable, and there is a much more rapid metamorphosis of tissue in carnivorous animals than in vegetable feeders. Whether the use of large quantities of meat increases the bodily strength or the mental faculties more than other kinds of nitrogenous food is uncertain. The great disadvantage of meat is the want of starch.

The composition of fresh and salt meat has been already given (pages 195 and 196); but the annexed table will supply further details:—

*Compositions of Fresh Beef. (Moleschott—Mean of all the Continental Analyses.)*

| | |
|---|---|
| Water, | 73·4 |
| Soluble albumen and hæmatin, | 2·25 |
| Insoluble albuminous substances, | 15·2 |
| Gelatinous substances, | 3·3 |
| Fat,* | 2·87 |
| Extractive matters, | 1·38 |
| Kreatin, | 0·068 |
| Ash, | 1·6 |

It is worthy of remark, that Stölzel † found 89 per cent. of carbonic acid in 100 of ash, which indicates probably lactic acid. Are the anti-scorbutic properties of fresh and raw (?) meat connected with this acid and is it destroyed by cooking? More than one-third of the ash is composed of phosphoric acid. It is alkaline.

Beef, mutton, and pork form the chief meats eaten by the soldier.

In time of peace he only receives as fresh meat, beef, and mutton, and more seldom pork; in time of war he has salt beef and salt pork.‡ The meat is supplied by contractors, or is, at some stations, furnished by the commissariat, who have their own slaughter-houses.

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* The amount of fat in this analysis is certainly too low.

† Liebig's Annalen, band lxxvii. p. 256.

‡ Professor Morgan of Dublin proposes the following plan of salting, which in certain cases might be usefully employed:—Immediately after death he opens the thorax, inserts a pipe into the left ventricle, and connects the pipe, by an india-rubber tube, with a tank of brine placed at a few feet elevation, and injects the vessel. After the blood has been driven out through the right auricle, the exit is closed, and the pressure forces the brine into the smallest ramifications of the vessels. The process is finished in ten to twenty minutes; the meat is then cut

The medical officer may be called on to see the animals during life, or to examine the meat.

### SUB-SECTION I.—INSPECTION OF ANIMALS.

Animals should be inspected twenty-four hours before being killed.* In this country killing is done twenty-four or forty-eight hours before the meat is issued; in the tropics only ten or twelve hours previously.

Animals should be well grown, well nourished, and neither too young nor too old. The flesh of young animals is less rich in salts, fat, and syntonin, and also loses much weight (40 to 70 per cent.) in cooking.

*Weight.*—An ox should weigh not less than 600 ℔, and will range from this to 1200 ℔. The French rules fix the minimum at 250 kilogrammes (= 550 ℔ av.) The mean weight in France is 350 kilogrammes (= 770 ℔ av.) A cow may weigh a few pounds less; a good fat cow will weigh from 700 to 740 ℔. A heifer should weigh 350 to 400 ℔. The French rules fix the minimum of the cow's weight at 160 kilogrammes (= 352 ℔). The mean weight of cows in France is 230 kilogrammes (= 506 ℔).

There are several methods of determining the weight; the one most commonly used in this country is to measure the length of the trunk from just in front of the scapulæ to the root of the tail, and the girth or circumference just behind the scapulæ; then multiply the square of girth by 0·08, and the product by the length, the dimensions in cubic feet are obtained; each cubic foot is supposed to weigh 42 ℔ avoirdupois. The formula is $(C^2 \times {\cdot}08) \times L \times 42$. An ox or cow gives about 60 per cent. of meat, exclusive of the head, feet, liver, lungs, and spleen, &c.†

A full-grown sheep will weigh from 60 to 90 ℔, but the difference in different breeds is very great. It also yields about 60 per cent. of available food.

A full-grown pig weighs from 100 to 180 ℔ or more, and yields about 75 to 80 per cent. of available food.

*Age.*—The age of the ox and cow should be from three to eight years; ‡ the age is told chiefly by the teeth, and less perfectly by the horns. The temporary teeth are in part through at birth, and all the incisors are through in twenty days; the first, second, and third pairs of temporary molars are through in thirty days; the teeth are grown large enough to touch each other by the sixth month; they gradually wear and fall in eighteen months; the fourth permanent molars are through at the fourth month; the fifth at the fifteenth; the sixth at two years. The temporary teeth begin to fall at twenty-one months, and are entirely replaced by the thirty-ninth to the forty-fifth month; the order being—central pair of incisors gone at twenty-one months; second pair of incisors at twenty-seven months; first and second temporary molars at thirty months; third temporary molars at thirty months

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up, dried, if necessary, in a hot air chamber, and packed in charcoal. The injected fluid is composed of 1 gallon of brine to the cwt., ¼ to ½ ℔ of nitre, 2 ℔ of sugar, a little spice, salt, and ½ oz. of phosphoric acid, which serves more completely to retain the albumen, and also adds a little phosphoric acid. The brine can be used hot. This is an excellent plan, but the meat is too salt.

* Every contract should have a clause giving officers the power of inspection.

† The animal is divided into carcass and offal; the former includes the whole of the skeleton (except the head and feet), with the muscles, membranes, vessels, and fat, and the kidneys and fat surrounding them. The offal includes the head, feet, skin, and all internal organs, except the kidneys.

‡ Dr Pavy gives four years for the highest perfection of ox beef, on the authority of an "intelligent and experienced grazier."

to three years; third and fourth temporary incisors at thirty-three months to three years. The development is quite complete at from five to six years. At that time the border of the incisors has been worn away a little below the level of the grinders. At six years the first grinders are beginning to wear, and are on a level with the incisors. At eight years the wear of the first grinders is very apparent. At ten or eleven years the used surfaces of the teeth begin to bear a square mark surrounded with a white line; and this is pronounced on all the teeth by the twelfth year; between the twelfth and fourteenth year this mark takes a round form.

The rings on the horns are less useful as guides. At ten or twelve months the first ring appears; at twenty months to two years the second; at thirty to thirty-six months the third ring; at forty to forty-six months the fourth ring; at fifty-four to sixty months the fifth ring, and so on. But at the fifth year, the three first rings are indistinguishable, and at the eighth year all the rings. Besides, the dealers file the horns.

In the sheep, the temporary teeth begin to appear in the first week, and fill the mouth at three months; they are gradually worn and fall about fifteen or eighteen months. The fourth permanent grinders appear at three months, and the fifth pair at twenty to twenty-seven months. A common rule is "two broad teeth every year." The wear of the teeth begins to be marked about six years.

The age of the pig is known up to three years by the teeth; after that there is no certainty. The temporary teeth are complete in three or four months; about the sixth month, the premolars, between the tusks and the first pair of molars, appear; in six or ten months the tusks and posterior incisors are replaced; in twelve months to two years the other incisors; the four permanent molars appear at six months; the fifth pair at ten months; and the sixth and last molars at eighteen months.

*Condition and Health.*—There ought to be a proper amount of fat, which is best felt on the false ribs and the tuberosities of the ischium, and the line of the belly from the sternum to the pelvis; the flesh should be tolerably firm and elastic; the skin should be supple.

As showing health, we should look to the general ease of movements, the quick bright eye, the nasal mucous membrane red, moist, and healthy-looking; the tongue not hanging; the respiration regular, easy; the expired air without odour; the circulation tranquil; the excreta natural in appearance.

When sick, the coat is rough or standing; the nostrils dry or covered with foam; the eyes heavy; the tongue protruded; the respiration difficult; movements slow and difficult; there may be diarrhœa; or scanty or bloody urine, &c. In the cow the teats are hot.

The diseases of cattle which the medical officer should watch for are—

1. *Epidemic Pleuro-pneumonia* (or lung disease).—Not easily recognised at first, but with marked lung symptoms after a few days.
2. *Foot and Mouth Disease* (murrain, aphtha, or eczema epizootica).—At once recognised by the examination of the mouth, feet, and teats.
3. *Cattle Plague* (typhus contagiosus, Steppe disease, Rinderpest).—Recognised by the early prostration (hanging of head, drooping of ears), shivering, running from eyes, nose, and mouth, peculiar condition of tongue and lips, cessation of rumination, and then by abdominal pain, scouring, &c.
4. *Anthrax* (malignant pustule, carbuncular fever).—If boils and carbuncles form, they are at once recognised; if there is erysipelas, it is called black-quarter, quarter-ill, or blackleg (erysipelas carbunculosum), and is easily seen.

5. *Simple inflammatory affections* of the lungs, bronchitis, and simple pneumonia. All have obvious symptoms.
6. *Dropsical affections* from kidney or heart disease.
7. *Indigestion*, often combined with apoplectic symptoms.

A great number of other diseases attack cattle, which it is not necessary to enumerate. All the above are tolerably easily recognised. The presence of *Tænia mediocanellata* cannot, to my knowledge, be detected before death.

The diseases of sheep are similar to those of cattle; they suffer also in certain cases from splenic apoplexy or "braxy," which is considered by Professor Gamgee to be a kind of anthrax, and is said to kill 50 per cent. of all young sheep that die in Scotland; the animals have a "peculiar look, staggering gait, blood-shot eyes, rapid breathing, full and frequent pulse, scanty secretions, and great heat of the body."*

The smallpox in sheep (variola ovina, *clavelée* of the French), is easily known by the flea-bitten appearance of the skin in the early stage, and by the rapid appearance of nodules or papulæ and vesicles.

The sheep is also subject to black-quarter (Erysipelas carbunculosum); one limb is affected; and the limp of the animal, the fever, and the rapid swelling of the limb, are sufficient diagnostic marks.

The sheep, of course, may suffer from acute lung affection, scouring, red water (hæmaturia); and many other diseases. Of the chronic lung affections, one of the most important is the so-called "phthisis," which is produced by the ova of the *Strongylus filaria*. This entozoon has not, I believe, been yet found in the muscles, and the meat is said to be good. The rot in sheep (fluke disease) is caused by the presence of the *Distoma hepaticum* in large numbers in the liver, and sometimes by other parasites. The principal symptoms are dulness, sluggishness, followed by rapid wasting and pallor of the mucous membrane, diarrhœa, yellowness of the eyes, falling of the hair, and dropsical swellings. The animal is supposed to take in the Cercaria (the embryotic stage of the distoma) from the herbage. The so-called "gid," "sturdy," or "turnsick," is caused by the development of the *Cœnurus cerebralis* in the brain.

The pig is also attacked by anthrax in different forms, by typhoid, and by hog cholera.† The swelling in the first case, and the scouring, fever, and prostration in the second, are sufficient diagnostic marks. In 1864, a severe fever of this kind, with or without scouring, prevailed among the pigs in London.

The so-called measle of the pig is caused by the presence in the muscle of the *Cysticercus cellulosæ*. It is detected in the following way:—The "measle trier" throws the pig on its back, draws out and wipes the tongue, and looks and feels for the sublingual vescicles containing the Cysticerci. Sometimes a bit is cut out of the muscle under the tongue, and the Cysticerci are microscopically examined. A small harpoon can be used for this purpose, and gives little pain. Sometimes the Cysticercus can be seen on the conjunctiva, or on the folds of the anus. When the disease is far advanced, the animal is dull, the eyes heavy, appetite bad. These symptoms are, however, not peculiar; there is said to be sometimes tenderness in the groin (Grève), but, according to Delpech, this is very uncertain; a better sign is a certain amount of swelling of the shoulder, which causes a sort of constriction of the neck, and somewhat impedes the movements of the animals (Delpech). The presence of the *Trichina spiralis* is indetectable before death, unless found in the muscles under the tongue.

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* Fifth Report of the Medical Officer to the Privy Council, p. 222.

† Dr Cobbold (Monthly Microscopical Journal, Nov. 1871) has lately pointed out that the pig is affected, both in America and Australia, with a large parasite (the *Stephanurus dentatus*). This worm is found chiefly though not solely in the fat, and is at first free and then encysted; the cyst is large, and may be 1⅜ inch in length and ⅓ inch in diameter. The full grown worm may be as much as 1⅓ inch in length. Three to six eggs are found in the cyst, and the young worms migrate. During their migration, it has been surmised that they cause the "hog cholera."

## SUB-SECTION II.—INSPECTION OF DEAD MEAT.*

### 1. *Fresh Meat.*

Meat should be inspected, in temperate climates, twenty-four hours after being killed; in the tropics, earlier.

The following points must be attended to:—

(*a*) *Quantity of Bone.*—In lean animals, the bone is relatively in too great proportion; taking the whole meat, 20 per cent. should be allowed.

(*b*) *Quantity and Character of the Fat.*—It should be sufficient, yet not excessive, else the relative proportion of albuminous food is too low; it should be firm, healthy looking, not like jelly, or too yellow; without hæmorrhage at any point. The kind of feeding has an effect on the colour of the fat; some oil-cakes give a marked yellow colour.

Professor Gamgee states that pigs fed on flesh have a peculiarly soft diffluent fat, and emit a strong odour from their bodies. The same authority tells us that the butchers will rub melted fat over the carcass of thin and diseased animals, to give the glossy look of health.

(*c*) *Condition of the Flesh.*—The muscles should be firm, and yet elastic; not tough; the pale moist muscle marks the young animal, the dark-coloured the old one; the muscular fasciculi are larger and coarser in bulls than oxen. A deep purple tint is said to indicate that the animal has not been slaughtered, but has died with the blood in it (Letheby). When good meat is placed on a white plate, a little reddish juice frequently flows out after some hours. Good meat has a marbled appearance from the ramifications of little veins of fat among the muscles (Letheby). There should be no lividity on cutting across some of the muscles; the interior of the muscle should be of the same character, or a little paler; there should be no softening, mucilaginous fluid, or pus, in the intermuscular cellular tissue. This is an important point, which should be closely looked to. The intermuscular tissue becomes soft, and tears easily when stretched in commencing putrefaction.

The degree of freshness of meat in commencing putrefaction is judged of by the colour, which becomes paler; by the odour, which becomes at an early stage different from the not unpleasant odour of fresh meat, and by the consistence. Afterwards, the signs are marked; the odour is disagreeable, and the colour begins to turn greenish.† It is a good plan to push a clean knife into the flesh up to its hilt. In good meat the resistance is uniform; in putrefying meat, some parts are softer than others. The smell of the knife is also a good test. Cysticerci and Trichinæ should be looked for (see below).

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* In the city of London, about 1 ton in 750 tons is condemned, but much escapes detection. Letheby (Lectures on Food, 2d edition, page 209) states that 700 tons of meat were destroyed. in seven years; of this, 805,653 ℔ were diseased; 568,375 ℔ were putrid, and 193,782 ℔ were from animals which had died of accident or disease. "In the city of London, the practice is to condemn the flesh of animals infected with certain parasites, such as measles and flukes, &c., and of animals suffering from fever or acute inflammatory affections, as rinderpest, pleuro-pneumonia, and the fever of parturition, and of animals emaciated by lingering disease, and those which have died from accident or from natural causes, as well as all meat tainted with physic, or in a high state of putrefaction." (Ibid, p. 210.) It may be a question if meat should be condemned in some of these cases, as, for instance, pleuro-pneumonia. In India, meat with Cysticerci is now ordered to be received, but to be carefully cooked; but it would be very difficult to ensure that proper cooking shall be always had recourse to.

† In diseased meat there is a disagreeable odour, sometimes a smell of physic; very discoverable when the meat is chopped up and drenched with warm water.

(*d*) *Condition of the Marrow.*—In temperate climates the marrow of the hind legs is solid twenty-four hours after killing; it is of a light rosy red. If it is soft, brownish, or with black points, the animals has been sick, or putrefaction is commencing. The marrow of the fore-legs is more diffluent; something like honey—of a light rosy red.

(*c.*) *Condition of Lungs and Liver.*—Both should be looked at, to detect the *Strongylus filaria* in the lungs; the Distoma in the liver; also for the presence of multiple abscesses.

(*f*) To detect cattle plague, the mouth, stomach, or intestines must be seen; no alterations have as yet been pointed out in the naked-eye appearance of the muscles, though under the microscope they are found to be degenerating like the muscles in human typhoid (Buchanan).

But meat cannot be fully judged of till it has been cooked, so as to see how much it loses in roasting or boiling; whether the fibres cook hard, &c.

In countries where there are goats, the attached foot of the sheep should be sent in for identification.

Decomposing sausages are difficult of detection until the smell alters. Artmann recommends mixing the sausage with a good deal of water, boiling and adding freshly-prepared lime-water. Good sausages give only a faint, not unpleasant, ammoniacal smell; bad sausages give a very offensive, peculiar ammoniacal odour.

### *Microscopic Examination of Meat.*

In the flesh of cattle, or of the pig, Cysticerci may be found. They are generally visible to the naked eye as small round bodies; when placed under a microscope with low power, their real nature is seen; they are sometimes so numerous as to cause the flesh to crackle on section. The smallest Cysticercus noticed by Leuckart in the pig was about $\frac{4}{100}$ths of an inch long and $\frac{3}{100}$ths broad; but they are generally much larger, and will reach to $\frac{2}{10}$ths or $\frac{3}{10}$ths or $\frac{3}{4}$ths of an inch. In some countries they are extremely common in cattle, and have been a source of considerable trouble in North-West India. The Cysticercus of the ox produces in man the *Tœnia mediocanellata.* In

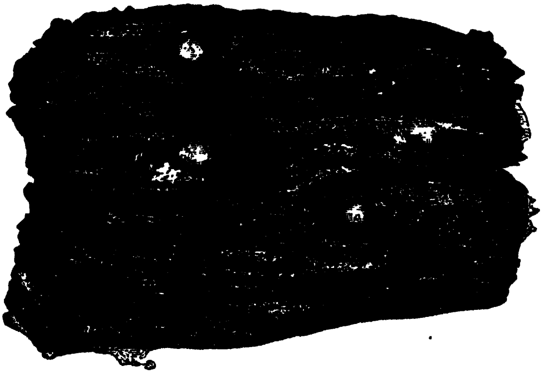

Fig. 29—Woodcut from a photograph of "measly" pork in Calcutta (natural size), by Dr. Lewis.

sheep Cobbold has described a small Cysticercus with a double crown of hooks, 26 in number. He thinks that possibly a special Tænia may arise from this.[*] In diagnosing the Cysticerci of pork the booklets should always be seen.

The Trichinæ may be present in the flesh of the pig; if encapsuled they will be seen with the naked eye as small round specks; but very often a microscope is necessary. A power of 50 to 100 diameters is sufficient. The best plan is to take a thin slice of flesh; put it into liquor potassæ (1 part to 8 of water), and let it stand for a few minutes till the muscle becomes clear; it must not be left too long, otherwise the Trichinæ will be destroyed. The white specks come out clearly, and the worm will be seen coiled up. If the capsule is too dense to allow the worm to be seen, a drop or two of weak hydrochloric acid should be added. If the meat is very fat, a little ether or benzine may be put on it in the first place. The parts most likely to be infected are said to be the muscular part of the diaphragm, the intercostal muscles, and the muscles of the eye and jaw.[†] In diagnosing Trichinæ, the coiled worm should be distinctly seen. The *Stephanurus dentatus* in the pig has been already referred to.

The so-called Psorospermia, or Rainey's capsules, must not be mistaken for the Trichinæ, nor indeed with care is error possible. These are little, almost transparent, bodies, found in the flesh of oxen, sheep, and pigs. They are in shape oval, spindle-shaped, or sometimes one end is pointed and the other rounded, or they are kidney-shaped. The investing membrane exhibits delicate markings, caused by a linear arrangement of minute hair-like fibres, which Mr Rainey[‡] states increase in size as the animal gets older. They sometimes are pointed, and the appearance under a high power (1000 diameters) is as if the investment consisted of very delicate, transparent, conical hairs, terminating in pointed process.[§] The contents of the cysts consist of granular matter, the granules or particles of which when mature are oval, and which adhere together, so as to form indistinct divisions of the entire mass. The length varies from $\frac{1}{300}$th to $\frac{1}{4}$th of an inch. They are usually narrow; they lie within the sarcolemma, and appear often not to irritate the muscle.

Till the present time no injurious effect has been known to be produced on men by these bodies, notwithstanding their enormous quantities in the flesh of domestic animals, nor have they been discovered in the muscles of men. But in pigs these bodies sometimes produce decided illness; besides general signs of illness, there are two invariable symptoms, viz., paralysis of the hind legs, and a spotty or nodular eruption.[||] In sheep they have been known to affect the muscle of the gullet, and produce abscesses, or what may be called so, viz., swellings sometimes as large as a nut, and containing a milky purulent-looking fluid, with myriads of these capsules in it. Sheep affected in this way often die suddenly.[¶]

It is by no means improbable that some effect on man may be hereafter discovered to be produced.

Some bodies which have been also termed Psorospermia, found in the liver of the rabbit, and other parts, and in the liver of man, and which have been

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[*] Surgeon-major Oldham describes *Cysticercus Tenuicollis* (from *Tænia marginata* of dog) as common in the sheep of the Punjab; it has four suckers and a double coronet of 32 hooks. (Indian Medical Gazette August, 1873).

[†] Lion—Comp. des Sanit., Pol. p. 171.

[‡] Phil. Trans. 1857.

[§] Beale, in third Report of the Cattle Plague Commission, Appendix.

[||] Virchow's Archiv, band xxxviii. p. 355.

[¶] Leisering, in Virchow's Archiv, band xxxvii. p. 431.

Roloff § has described little hard round nodules in the flesh of the pig, some seem very small, others as large as the head of a pin, with little prolongations running to the surrounding muscular fibres to which they are attached. On the outside of these bodies are bundles of fine hairs or needles, sometimes arranged in quite a feather-like form. The bodies have a great resemblance to the guanin bodies of Virchow, but the needles are not crystalline. Roloff puts the question if these bodies are of post-mortem origin.

It is hardly necessary to state that in cutting across meat, *small bits of* tendons or fascia, sometimes very like a little cyst, will be found; but common care will prevent a mistake.

### 2. *Salt Meat.*

It is not at all easy to judge of salt meat, and *the test of cooking must often* be employed. The following points should be attended to:—

(*a*) *The salting has been well done, but the parts inferior.*—This is at once detected by *taking out a good number* of pieces; those at the bottom of the cask should be looked at, as well as those at the top.

(*b*) *The salting well done, and the parts good, but the meat old.*—Here the extreme hardness and toughness, and shrivelling of the meat, must guide us. It would be desirable to have the year of salting placed on the cask of salt beef or pork.

(*c*) *The salting well done, but the meat bad.*—If the meat has partially putrefied, no salting will entirely remove its softness; and even there may be putrefactive odour, or greenish colour. A slight amount of decomposition is arrested by the salt, and is probably indetectable. Cysticerci are not killed by salting, and can be detected. Measly pigs are said to salt badly, but Mr Gamgee informs me this is not the case.

(*d*) *The salting badly done, either from haste or bad brine.*—In both cases signs of putrefaction can be detected; the meat is paler than it should be; often slightly greenish in colour, and with a peculiar odour.

It should be remembered that brine is sometimes poisonous; this occurs in cases where the brine has been used several times; a large quantity of animal substance passes into it, and appears to decompose. The special poisonous agent has not been isolated.

## SUB-SECTION III.—DISEASES ARISING FROM ALTERED QUALITY OF MEAT.

A very considerable quantity of meat from diseased animals is brought into the market, but the amount is uncertain.

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* Leuckart, Die Menschl. Paras. band i. p. 740; Stieda, Virchow's Archiv, band xxxii. p. 132; Roloff, Virchow's Archiv, band xliii. p. 512.

† Virchow's Archiv, band xxxiii. p. 549.

‡ Ibid. band xxxv. 358.

§ Virchow's Archiv, band xliii. p. 524.

Instances are not at all uncommon in which persons, after partaking of butcher's meat, have been attacked with serious gastro-intestinal symptoms (vomiting, diarrhœa, and even cramp), followed in some cases by severe febrile symptoms; the whole complex of symptoms somewhat resembles cholera at first, and afterwards typhoid fever. The meat has been often analysed, for the purpose of detecting poison, but none has been found.* In the records of these cases, the kind of meat, the part used, and the origin from a diseased animal, are not stated, and, in some cases, it may be conjectured that the cooking, and not the meat, was in fault. Still, the instances are becoming numerous, and are increasing every day, as attention is directed to the subject. We should conclude from general principles, that as all diseases must affect the composition of flesh, and as the composition of our own bodies is inextricably blended with the composition of the substances we eat, it must be of the greatest importance for health to have these substances as pure as possible. Animal poisons may indeed be neutralised or destroyed by the processes of cooking and digestion, but the composition of muscle must exert an influence on the composition of our own nitrogenous tissues which no preparation or digestion can remove.

On looking through the literature of the subject, however, we find less evidence than might be expected. I cannot but believe this to be, in part, owing to imperfect observation, especially when we think for how long a time the Trichina disease was overlooked.

1. *The flesh of healthy animals may produce Poisonous Symptoms.*—This is the case with certain kinds of fish, especially in the tropical seas. There is no evidence that the animal is diseased, and the flesh is not decomposed; it produces, however, violent symptoms of two kinds—gastro-intestinal irritation, and severe ataxic nervous symptoms, with great depression and algidity. The little herring (*Clupea harengo minor*), the silver-fish (*Zeus gallus*), the pilchard, the white flat-fish, and several others, have been known to have these effects.† In some cases, though not in all, the poison is developed during the breeding time. Oysters (even when in season) and mussels have been known to produce similar symptoms, without any decomposition. The production of dyspepsia and nettle-rash in some persons from eating shell-fish need scarcely be mentioned.

Among the Mammalia the flesh of the pig sometimes causes diarrhœa—a fact I have had occasion to observe in a regiment in India, and which has been often noticed by others. The flesh is probably affected by the unwholesome garbage on which the pig feeds. Sometimes pork, not obviously diseased, has produced choleraic symptoms.‡ In none of these cases has the poison been isolated.

2. *The flesh of healthy animals when decomposing*, is eaten sometimes without danger; but it occasionally gives rise to gastro-intestinal disorder—vomiting, diarrhœa, and great depression; in some cases severe febrile symptoms occur, which are like typhus, on account of the great cerebral complication. Cooking does not appear entirely to check the decomposition.

It appears to be, in some cases, the acid fluids of cooked meat which promote this alteration.

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* See Professor Gamgee's paper in the Fifth Report of the Medical Officer to the Privy Council, 1863, p. 287. He refers to cases noted by Maclagan, Taylor, Letheby, Dundas Thomson, and Keith.

† A list of more than forty fishes, which are occasionally poisonous, is given by Pappenheim.—*Hand. der Sanitats-Pol.* band i. p. 395.

‡ Kesteven cites a good case in which twelve persons were affected.—*Med. Times and Gazette*, March 5, 1864.

Sausages and pork-pies* sometimes become poisonous from the formation of an as yet unknown substance, which is perhaps of a fatty nature. It is not trimethylamine, amylamine, or phenylamine—these are not poisonous (Schlossberger). The symptoms are severe intestinal irritation, followed rapidly by nervous oppression and collapse.† Neither salts nor spices hinder the production of this poison. M. Vandem Corput attributes the poisonous effects of sausages to a fungus, of the nature of a sarcina, or what he terms *Sarcina botulina.*‡

Oysters and shell-fish, when decomposing, produce also marked symptoms of the same kind. Rotten fish are used, however, by the Burmese, Siamese, and Chinese as a sort of condiment, without bad effects.

3. *The fresh and not decomposing flesh of diseased animals* causes in many cases injurious effects. A good deal of difference of opinion, however, exists on this point, and it would seem that a more careful inquiry is necessary. The probability is, that when attention is directed to the subject, the effects of diseased meat will be found to be more considerable than at present believed.§ At the same time, we must not go beyond the facts as they are at present known to us, and at present certainly bad effects have been traced in only a few instances; perhaps the heat of cooking is the safeguard.

(*a*) *Accidents.*—The flesh of animals killed on account of accidents may be eaten without injury.

(*b*) The flesh of over-driven animals is said by Professor Gamgee to contain a poison which often produces eczema on the skin of those who handle it; and eating the flesh is said to "have been attended with bad effects."

(*c*) *Early Stage of Acute Inflammatory Disease.*—The meat is not apparently altered, and it is said that some of the primest meat in the London market is taken from beasts in this condition; it is not known to be injurious, but it has been recommended that the blood should be allowed entirely to flow out of the body, and should not be used in any way.

(*d*) *Chronic wasting Diseases—Phthisis, Dropsy, &c.*—The flesh is pale, cooks badly, and gives rise to sickness and diarrhœa. It also soon begins to decompose, and then causes very severe gastro-intestinal derangement.

(*e*) *Chronic Nervous Fevers.*—Same as above.

(*f*) *Epidemic Pleuro-pneumonia of Cattle.*—Much doubt exists as to the effect of this disease on the meat. It is hardly possible that the flesh should not be seriously altered in composition, but it seems certain that a large quantity is daily consumed without apparent injury. I have been informed by two most excellent authorities that the Kaffirs ate their cattle when destroyed by the epidemic lung disease which prevailed at the Cape some years ago, without injury. Both my informants—Staff-surgeon Nicolson and Assistant-surgeon Frank—made very careful inquiries on this point. Dr Livingstone, however, states that the use of such flesh produces carbuncle.

(*g*) *Anthrax and Malignant Pustule.*—Many of the older authors (Ramazzini, Lancisi, quoted by Levy) mention facts tending to prove the danger of using the flesh of animals affected with malignant pustule. Chaussier also affirmed the same thing, but subsequently modified his opinion considerably. The apparent increase in the number of cases of malignant pustule in men has been ascribed to eating the flesh of animals with this disease, but it is quite as likely that inoculation may have taken place in other ways.

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* I have seen very severe symptoms produced, diarrhoea and partial collapse, from eating beefsteak pie, which presented nothing unpleasant to the taste. (F. de C.)

† A severe case of poisoning by liver sausages took place at Middelburg in Holland, in March 1874. Nearly 400 were attacked, and out of 343 reported cases, 6 died. The symptoms commenced a few hours after the sausages were eaten, consisting of nausea and vomiting, diarrhœa with offensive stools and abdominal pain and high fever. The symptoms, after apparent convalescence, recurred for several days, and at last became quite of an intermittent character. Chemical and microscopical examination failed to detect anything, except that there were quantities of the minutest organisms in the sausages. (Centralblatt für die Med. Wiss. 1875, No. 14, p. 219.)

‡ Quoted by Letheby, *Chemical News*, Feb. 1869. I have not seen the original paper.

§ Professor Gamgee says that ⅕th of the meat in London is more or less diseased.

The evidence laid before the Belgian Academy of Medicine led them to believe the flesh of cattle affected with carbuncular fevers to be injurious, and it is not allowed to be sold.

It has been supposed that the outbreaks of boils, which have certainly become more prevalent of late years, are produced by meat of this kind, but the evidence is very imperfect.

Menschel* has recorded a case in which twenty-four persons were seized with malignant pustule, the majority after eating the flesh of beasts suffering from the disease, the others from direct inoculation. Those who ate the flesh were attacked in three or ten days; those who were inoculated, in three to six days. In those who ate the flesh the carbuncle appeared in two cases on the upper arm, in three on the forearm, in nine on the face and head. The gangrenous degeneration rapidly extended. Five died of the twenty-four cases. One woman ate flesh and broth; another ate the same flesh, but threw away the broth. The first was attacked—the second had only diarrhœa. This appears to be the most satisfactory case on record. It is also stated that pigs fed on the flesh got the disease, and that a woman who ate some of the diseased pork was also attacked.

On the other hand, several old authors, and lately Neffel,† assert that the Kirghises constantly eat horses and cattle (either killed or dying spontaneously) affected with malignant pustule without injury.

Parent-Duchâtelet (t. ii. p. 196) quotes a case from Hamel (1737), in which a bull infected three persons who aided in killing it, and a surgeon who opened one of the tumours of a person affected; yet, of more than 100 persons who ate the flesh roasted and boiled, no one experienced the slightest inconvenience, and Parent states that many other cases are known in literature.

Parent-Duchâtelet and Levy (t. ii. p. 661) quote from Morand' (1766) an instance in which two bulls communicated malignant pustule to two butchers by inoculation, yet the flesh of the animals was eaten at the "Invalides" without injury. But both these instances are of old date. Pappenheim (*Handb. der Sanitats-Pol.*, band i. p. 587) states (without giving special instances) that there are many cases in which no bad effect resulted from the cooked flesh of charbon—that the peasants of Posen eat such meat with perfect indifference, and believe it is harmless when boiled.

With regard especially to the erysipelas carbunculosum, or black-quarter, as distinguished from malignant pustule (if it is to be so distinguished), Professor Gamgee ("Fifth Report of Medical officer to the Privy Council," p. 290) refers to cases of poisoning, and two deaths mentioned to him by Dr Keith of Aberdeen, caused by eating an animal affected with black-quarter. He also notices an instance which occurred "a number of years ago in Dumfriesshire," when seventeen persons were more or less affected, and at least one died, and states that a number of cases have been related to him by different observers.

The discrepancy of evidence is so great as to lead to the conclusion, that the stage of the disease, or the part eaten, or the mode of cooking must have great influence, and that a much more careful study than has yet been given to this subject is necessary to clear up these *great variations* of statement.

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* Preuss. Med. Zeit. 4th June 1862, and Canstatt's Jahresb. 1862, band iv. p. 257.

† Canstatt's Jahresb. for 1860, band ii. p. 137.

(*h*) *Splenic Apoplexy or Braxy of Sheep.*—Professor Simonds[*] states that pigs and dogs died in a few hours after eating the flesh of sheep dead of braxy. Professor Gamgee ("Privy Council Report," 1863, p. 280) affirms the same thing; but, on the other hand, I am informed by my friend Dr M'Gregor that dogs eat the meat with perfect impunity. The experiments of Alfort (Levy, t. ii. p. 664) have also shown that pigs, dogs, and fowls are not incommoded by this poison, which yet acts violently when swallowed by sheep, goats, or horses. So also Dr Smith states,[†] that the shepherds in the highlands of Scotland eat by preference braxy sheep, and are quite healthy. Dr M'Gregor tells me that the flesh of braxy sheep is never cooked until it has been steeped for two months in brine, and then suspended for a time from the kitchen roof. It is preferred to ordinary salt mutton, because it has rather a flavour of game.

(*i*) *Small-pox of Sheep.*—The flesh has a peculiar nauseous smell, and is pale and moist. It produces sickness and diarrhœa, and sometimes febrile symptoms.

(*j*) *Foot-and-mouth Disease* (*Aphtha* (*or Eczema*) *epizootica*).—Levy[‡] states that at different times (1834, 1835, 1839) the aphthous disease has prevailed among cattle both at Paris and Lyons, without the sale of the meat being interrupted or giving rise to bad results. The milk of cows affected with foot-and-mouth disease has been supposed to cause vesicular affection of the mouth in men.[§] The evidence seems to me very uncertain. The discharges from the mouth are constantly on the hands of the farm-labourers, who are not very cleanly, and who must constantly convey them to their own mouths, and yet these discharges, so infectious to other cattle, produce no effect on them.

(*k*) *Cattle Plague* (*Rinderpest, Typhus contagiosus of the French.*)—*A priori*, such flesh would be considered highly dangerous, and the Belgian Academy of Medicine so consider it; but there is some strong evidence on the other side. In Strasbourg and in Paris, in 1814, many of the beasts eaten in those cities for several months had rinderpest, and yet no ill consequences were traced. But it may be questioned whether they were looked for in that careful way they would be at the present day.[‖] Some other evidence is stronger: Renault, the director of the Veterinary School at Alfort, made for several years after 1828 many experiments, and asserts that there is no danger from the *cooked* flesh of cattle, pigs, or sheep dead of any contagious disease (quelle que soit la repugnance bien naturelle que puissent inspirer ces produits.")[¶] So also during the occurrence of the rinderpest in England (1865), large quantities of the meat of animals killed in all stages of the disease were eaten without ill effects. In Bohemia also, in 1863, the peasants dug up the animals dead with rinderpest, and ate them without bad results.[**]

(*l*) Rabies in the dog and cow produces no bad effects.[††]

(*m*) Diseases in the pig, like scarlet fever and pig-typhus, have prevailed lately in London, and the flesh has been eaten. No injury has been proved.[‡‡]

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[*] Agricultural Journal, No. 50, p. 232.

[†] Social Science Trans. for 1863, p. 559.

[‡] Traité d'Hygiène, 1857, t. xi. p. 663.

[§] Jour. of the Epid. Soc., vol. i. p. 423.

[‖] The words of Coze (Parent-Duchâtelet, t. xi. p. 201) are, however, very strong. At Strasbourg he says—" Un millier de bœufs de grande taille, malades pour la plupart au plus haut degré, puisqu'un assez grande nombre out été égorgés au moment ou ils allerènt expirer, a été consommé, pendant et après le blocus, et cet aliment n'a produit aucune maladie."

[¶] Payen, Des Substances Alimentaires, pp. 30, 31.

[**] Evidence of Cattle Plague Commission, question 997, and other places.

[††] Parent-Duchâtelet, t. ii. p. 197, cites a case of seven mad cows being sold without injury to those who ate the flesh.

[‡‡] Letheby, *Chem. News*, Jan. 15, 1869.

(*n*) The *Cysticercus cellulosæ* of the pig produces *Tænia solium*, and that of the ox and cow the *Tænia mediocanellata*. These entozoa often arise from eating the raw meat, but neither cooking nor salting are quite preservative, though they may lessen the danger. Smoking appears to kill the Cysticerci, and so, according to Delpech, does a temperature of 212° Fahr. T. Lewis* found that a much lower temperature sufficed. When the Cysticerci had been exposed for five minutes to a heat of 130° Fahr., he could detect no movements, and he considers that a temperature of from 135° to 140° for five minutes would certainly kill them. Lewis considers there is no danger if the cooking is well done, as the temperature of well done meat is never below 150°.

(*o*) The *Trichina spiralis* in the pig gives rise to the curious Trichina disease caused by the wanderings of the young Trichinæ. The affection is highly febrile, resembling typhoid or even typhus, or acute tuberculosis, but attended with excessive pains in the limbs, and œdema.† Boils are also sometimes caused. The eating of raw trichiniferous pork is the chief cause, and the entozoon is not easily killed by cooking or salting. A temperature of 144° to 155° Fahr. kills the free Trichinæ, but the encapsuled Trichinæ may demand a greater heat (Fiedler). During cooking, a temperature which will coagulate the albumen (150° to 155° Fahr.) renders the Trichinæ incapable of propagation, or destroys them. As a practical rule, it may be said that if the interior of a piece of boiled or roasted pork retains much of the blood-red colour of uncooked meat, the temperature has not been higher than 131° Fahr., and there is still danger. Intense cold and complete decomposition of the meat do not destroy the Trichinæ. Hot smoking, when thoroughly done, does destroy them (Leuckart); but the common kinds of smoking, when the heat is often low, do not touch the Trichinæ (Küchenmeister).

(*p*) The *Echinococcus Disease.*—It is well known that many persons will eat freely of, and even prefer, the liver of the sheep full of flukes. I am not aware that in this country direct evidence has been given of the production of disease from this cause. In Iceland the Echinococcus disease, which affects a large number of persons, is derived from sheep and cattle, who in their turn get the disease from the Tænia of the dog (Leared and Krabbe.)

(*q*) Glanders and farcy in horses do not appear to produce any injurious effects on their flesh when eaten as food. Parent-Duchâtelet quotes two instances, in one of which 300 glandered horses were eaten without injury. ("Hyg. Publ.," t. ii. 194. See also Levy, t. ii. pp. 661, 662.) In 1870, during the siege of Paris, large quantities of flesh from horses with farcy and glanders were eaten without injury.

(*r*) Medicines, especially antimony,‡ given to the animals in large quantities, have sometimes produced vomiting and diarrhœa. Arsenic, also, is occasionally given, and the flesh may contain enough arsenic to be dangerous.§

In time of peace the duty of the army surgeon is simple. Under the terms of the contract, all sick beasts are necessarily excluded. Without reference, then, to any uncertain questions of hurtfulness, or the reverse, he must object to the use of the flesh of such animals. This is the safe and proper course.

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* The Bladder Worms found in Beef and Pork, by T. R. Lewis, M.D., Calcutta, 1872.

† Aitken's Practice of Medicine, 4th edit. vol. i. p. 857. See also reports on Hygiene by the writer in the Army Medical Report for 1860, 1861, 1862, and 1863, where references to most of the early cases will be found. See also Dr Thudichum's treatise in Mr Simon's Report to the Privy Council, 1864.

‡ See a well marked case cited by Pavy ("A Treaties on Food and Dietetics," 2d ed. 1875, p. 160), as quoted by Gamgee, from the Central Zeitung für die gesammte Veterinärmedizin für 1854, where 107 persons were attacked after eating the flesh of an ox which had been treated with tartar-emetic, previous to being slaughtered.

§ Levy, Traité d'Hygiène, t. ii. p. 666; reference to experiments of Danger, Haudin, and Chatin.

But, in time of war, he may be placed in the dilemma of allowing such meat to be used, or of getting none at all. He should then allow the issue of the meat of all animals, ill with inflammatory and contagious diseases, with the exception of small-pox, and perhaps splenic apoplexy in sheep. But it will be well to take the precautions—*1st*, Of bleeding the animals as thoroughly as possible; *2d*, Of using only the muscles, and not the organs, as it is quite possible these may be more injurious than the muscles, though there are no decided facts on this point; and, *3d*, Of seeing that the cooking is thoroughly done. But animals with small-pox, Cysticerci, and Trichinæ, should not be used. If dire necessity compels their use, then the employment of a great heat in a baker's oven and smoking, if it can be used, may lessen the danger. If such things can be got, it would be well to try the effect on the meat of antiseptics, especially of carbolic acid, which destroys low animal life with great certainty.

## SUB-SECTION IV.—COOKING OF MEAT.

*Boiling.*—The loss of weight is about 20 or 30 per cent., sometimes as much as 40. If it is wished to retain as much as posible of the salts and soluble substances in the meat, the piece should be left large, and should be plunged into boiling water for five minutes to coagulate the albumen. After this the heat can scarcely be too low. The temperature of coagulation of the albuminoid substances differs in the different constituents, one kind of albumen coagulates at as low a heat as 86° if the muscle serum be very acid; another albumen coagulates at 113° Fahr.; a large quantity of albumen coagulates at 167°, the hæmatoglobulin coagulates at 158° to 162°, below which temperature the meat will be underdone. If the temperature is kept above 170°, the muscular tissue shrinks, and becomes hard and indigestible. Liebig recommends a temperature of 158° to 160°. Most military cooks employ too great a heat: the meat is shrunken and hard. In boiling, sulphhydrate of ammonium is evolved, with odoriferous compounds, and an acid like acetic acid.

If it is desired to make good broth, the meat is cut small, and put into cold water, and then warmed to 150°; beef gives the weakest broth. In a pint there are about 150 grains of organic matter, and 90 grains of salts. Mutton broth is a little stronger, and chicken broth strongest of all. About 82 per cent. of the salts of beef pass into the broth, viz., all the chlorides, and most of the phosphates.

Broth made without heat, by the addition of four drops of hydrochloric acid to a pint of water, and a half pound of beef is richer in soluble albumen. Lactic acid and chloride of potassium added together have the same effect. If rather more hydrochloric acid be used, but no salt, heat can be applied, and, if not higher than 130° Fahr., nearly 50 per cent. of the meat can be obtained in the broth.

*Roasting.*—The loss varies from 20 to 35 per cent.; in beef, it is rather less than in mutton (Oesterlen). This loss is chiefly water; the proportion of carbon, hydrogen, nitrogen, and oxygen remaining the same (Playfair). Roasting should be slowly done; to retain the juices, the meat must be first subjected to an intense heat, and afterwards cooked very slowly; the dry distillation forms aromatic products, which are in part volatilized; the fat is in part melted, and flows out with gelatine and altered extractive matters.

The fat often, improperly, becomes the perquisite of the cook, and may be lost to the soldier. The loss in baking is nearly the same, or a little less.

*Stewing.*—This is virtually the same as roasting, only the meat is cut up, is continually moistened with its own juices, and is often mixed with vegetables. Like boiling and roasting, it should be done slowly at a low heat; the loss then is about 20 per cent., and chiefly water.

In all cases, there is one grand rule, viz., to cook the meat slowly, and with little heat, and, as far as possible, to let the loss be water only. The fault in military kitchens has been, that excessive heat is used. I have frequently seen the water boiling, and the men have told me that, in order to boil the vegetables, and yet not overdo the meat, they are obliged to remove the meat for a time from the water. The meat is then often a sodden, tasteless mass, with hard, shrunken, and indigestible fibres. The thermometer will be found very useful, especially in showing cooks that the temperature is often much higher than they think. In the cooking of salt meat, the heat should be very slowly applied, and long continued; it is said that the addition of a little vinegar softens the hard sarcolemma, and it is certain that vinegar is an agreeable condiment to take with salt meat, and is probably very useful. It may be of importance to remember this in time of war.

In cutting up meat, there is a loss of about 5 per cent., and there is also a loss from bone, so that, all deductions being made, the soldier does not get more than 5 or 6 ounces of cooked meat out of 12 ounces.

The large quantity of flesh extract contained in the brine can be obtained by dialysis. Place the filtered brine in a bladder or vessel of the prepared dialysis parchment, and place it in a large vessel with water; the salt diffuses out, leaving, in three or four days, the extract behind; from two gallons of brine a fluid was obtained, which, on evaporation, yielded 1 lb of extract. (Whitelaw, *Chemical News*, March 1864.) The liquid left in the dialyser may be mixed with flour, and then forms a nutritious meat-biscuit (Whitelaw). Instead of pure water in the outer vessel, salt water may be at first used. An air-bladder will do as a dialyser if the parchment cannot be obtained.

### SUB-SECTION V.—PRESERVATION OF MEAT.

Meat may be kept for some time by simply heating the outside very strongly, so as to coagulate the albumen; or by placing it in a close vessel, in which sulphur is burnt, or by covering the surface with charcoal, or strong acetic acid, or calcium bisulphite, or weak carbolic acid. Injections of alum and aluminium chloride through the vessels will preserve it for a long time; water should be injected first, and then the solution. Even common salt injected in the same way will keep it for some time. So also will free exposure to pure air; charcoal thrown over it, and suspended also in the air; or the meat being cut into smaller portions, and placed in a large vessel, heat should be applied, and, while hot, the mouth of the vessel should be closed tightly, with well washed and dried cotton-wool; the air is filtered, and partially freed from germs. The application of sugar to the surface is also a good plan.*

Plans of this kind may be useful to medical officers under two circumstances, viz., on board ship, and in sieges, when it is of importance to preserve every portion of food as long as possible. The covering the whole surface with powdered charcoal is perhaps as convenient as any plan. A coating of paraffin, and many other plans of excluding air, are also used.

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* Cold is a great preservative of meat; in ice it can be preserved for an unlimited period, but appears to decompose very rapidly in thawing. The fresh meat now imported so largely from America is kept at a temperature above the freezing point; about 38°F.

Meat is also preserved in tin cases, either simply by the complete exclusion of air (Appert's process), or by partly excluding air, and destroying the oxygen of the remaining part by sulphite of soda (M'Call's process). It is not necessary to raise the heat so high in this case, and the meat is less sapid. Meat prepared in either way has, it is said, given rise to diarrhœa, but this is simply from bad preparation : when well manufactured it has not this effect. (See also chapter on CONCENTRATED FOOD.)

Meat is also preserved by drawing off the air from the case, and substituting nitrogen and a little sulphurous acid (Jones and Trevithick's patent), or the air can be heated to 400° or 500°, so as to kill all germs (Pasteur), and then allowed to flow into an exhausted flask.*

## SECTION II.

## WHEAT.

*Advantages as an Article of Diet.*—It is poor in water and rich in solids, therefore very nutritious in small bulk ; when the two outer coats are separated, the whole grain is digestible. The nitrogenous substances are large and varied,† consisting of soluble albumen (1 to 2 per cent.) and gluten (8 to 12 per cent.), which itself consists of four substances, which are named by Ritthausen,‡ gluten-casein, gliadin (or vegetable gelatine or glutin), gluten-fibrin, and mucedin.§ The starchy substances (starch, dextrin, sugar) are

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* Those who wish to see a good account of the different patents for the preservation of meat and other foods, should refer to Dr Letheby's Cantor Lectures on Food, delivered before the Society of Arts in 1860. 2d edition, 1872.

† This reaches 14 to 15 per cent., especially in the hard wheats of Italy and Sicily, which are used for macaroni (Letheby).

‡ Die Eiweisskörper der Getreidearten, von Dr H. Ritthausen, 1872.

§ These are the substances found by Ritthausen. The older writers use rather different terms. According to Ritthausen (*op. cit.* p. 31, *et seq* ) gluten-casein is insoluble in cold spirit ; it was formerly called vegetable fibrin, but was not obtained pure ; it forms from 26 to 31·4 per cent. of dry gluten. Gliadin, gluten-fibrin, and mucedin, are soluble in spirit, and form from 34 to 42 of the gluten ; fat forms from 5 to 6, and bran and starch make up from 16 to 18 per cent. ; there is a large remainder of loss.

*The Composition of the substances is* (Ritthausen, p. 68)—

| | Casein. | Gliadin. | Mucedin. | Fibrin. |
|---|---|---|---|---|
| Carbon, | 25·94 | 52·76 | 54·11 | 54·31 |
| Hydrogen, | 7·04 | 7·10 | 6·90 | 7·18 |
| Nitrogen, | 17·14 | 18·01 | 16·63 | 16·89 |
| Oxygen, | 21·92 | 21·37 | 21·48 | 20·61 |
| Sulphur, | ·96 | ·85 | ·88 | 1·01 |

The amount of nitrogen in the flour increases tolerably regularly with the gluten. A portion of a table given by Ritthausen (Die Eiweisskörper, p. 15) will show the amount of nitrogen when the gluten has been determined.

| Weight of dry gluten per cent. | Nitrogen per cent. | Weight of gluten per cent. | Nitrogen per cent. |
|---|---|---|---|
| 9·11 | 1·60 | ... | ... |
| 9·54 | 1·62 | 12·33 | 2·04 |
| 10·65 | 1·65 | 12·33 | 2·05 |
| 8·52 | 1·68 | 12·64 | 2·15 |
| 8·36 | 1·71 | ... | ... |
| 11·27 | 1·75 | 14·80 | 2·43 |
| ... | ... | 15·56 | 2·53 |
| 10·41 | 1·78 | 13·85 | 2·64 |
| 12·45 | 1·93 | 14·88 | 2·66 |
| 11·10 | 1·94 | ... | ... |
| ... | ... | 13·07 | 2·68 |
| 12·13 | 2·03 | ... | ... |
| ... | ... | 17·00 | 2·75 |

The increase is not perfectly regular, but is sufficient to prove the relation.

The mean amount of nitrogen in the dry gluten itself is 13·64, and it varies from 12·54 to 15·25 per cent. (Ritthausen, *op. cit.* p. 16).

large, 60 to 70 per cent., and are easily digested; and, according to Mége-Mouriès, a nitrogenous substance (cerealin) is contained in the internal envelope, which, like diastase, acts energetically in transforming starch into dextrin, sugar, and lactic acid. Some consider this cerealin to be merely a form of diastase. Cholestrine is found in wheat, but in very small quantity (Ritthausen). The salts are chiefly phosphates of potash and magnesia.

*Disadvantages.*—It is deficient in fat, and in vegetable salts which may form carbonates in the system.

As usually prepared, the grain is separated into flour and bran; the mean being 80 parts of flour, 16 of bran, and 4 of loss. The flour is itself divided into best or superfine, seconds or middlings, pollards or thirds or bran flour. In different districts different names are used. The wheats of commerce are named from colour or consistence (hard or soft); the hard wheat contains less water, less starch, and more gluten than the soft wheat.

### SUB-SECTION I.—WHEAT GRAINS.

The medical officer will seldom be called on to examine wheat grains, but if so, the following points should be attended to. The grains should be well filled out, of not too dark a colour; the furrow should not be too deep; there should be no smell, no discoloration, and no evidence of insects or fungi. The heavier the weight the better. In the Belgian army the minimum weight is 77 kilogrammes the hectolitre.[*] In England, good wheat weighs 60 lb to the bushel; light wheat 58 lb or even 50 lb. The fungi, if present, will be found at the roots of the hairs, and if in small amount, are only microscopic. If in large amount they cause the diseases known by the name of rust, bunt or smut, or dust brand; they are owing to species of Uredo and Puccinia. (See FLOUR.[†]) If any grains are seen pierced with a hole, and on examination are found to be a mere shell, with all the starch gone, this is owing to the weevil, and the little insect can itself be found readily enough if a handful of wheat be taken and spread over a large plate. The weevil can hardly escape being seen. (See figs. 40 and 41, p. 229.) The *Acarus farinæ* (see p. 229) may also prey on the wheat grain, but cannot be seen without a microscope.

### SUB-SECTION II.—FLOUR.[‡]

Almost all the bran is separated from the finest flour; it has been a question whether this is desirable, as the bran contains nitrogenous matter—as much

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[*] Squillier, Des Subsist. Mil. p. 37.

[†] The brand of wheat and other cereals is owing to the Uredo or Puccinia, the species being *sitophilum* or *segetum*. Rye, maize, millet, &c., appear to have their own species.

[‡] The following, after Peligot (mean of 14 analyses), may be taken as the mean composition of flour. The analyses of Von Bibra (Die Getreidearten und das Brod, 1860) agree very closely with it.

| *Wheat Flour and Bran.* | In 100 parts. | |
|---|---|---|
| | Flour. | Bran. |
| Water, | 14 | 10·3 |
| Fatty matters, | 1·2 | 2·82 |
| Nitrogenous substances insoluble in water (gluten), | 12·8 | 10·84 |
| Nitrogenous substances soluble in water (albumen), | 1·8 | 1·64 |
| Non-nitrogenous soluble substances (dextrin, sugar), | 7·2 | 5·8 |
| Starch, | 59·7 | 22·62 |
| Cellulose, | 1·7 | 43·98[§] |
| Salts, | 1·6 | 2·52 |

[§] This is however the cellulose of the entire grain, both of the husk and the interior of the grain. Potash, phosphoric acid, and magnesia are the principal ingredients of the salts; the earthy phosphates are specially combined, and in definite proportions, with the albuminates (Mayer), and also the gummy matter Bibra). The alkaline phosphates are free. The bran contains much silica. Oudemans places the cellulose ower (25 to 30 per cent.), and the salts higher (4 to 6 per cent.).

sometimes as 15 per cent., with 3·5 per cent. of fat, and 5·7 per cent. of salts. But if the bran is used, it seems probable that much is left undigested, and all the nutriment which is contained in it is not extracted. A plan has been employed by Mége-Mouriès, which seems to save all the most valuable parts of the bran; the two or three outer and highly siliceous envelopes of the wheat are detached, and the fourth or internal envelope is left. Several plans of decorticating wheat have been proposed, but none of them at present have superseded the old system of grinding.

If the whole wheat is used, it should be ground very fine, as the harder envelopes are very irritating, and it is well to remember that for sick persons with any bowel complaints bread must be used entirely without bran. I have found dysenteries most intractable merely from attention not being directed to this simple point.

### *Examination of Flour for Quality and Adulteration.*

Flour should be examined physically, microscopically, chemically, and practically by making bread.

The quality is best determined by chemical examination; adulterations by the microscope.

#### *Physical Examination.*

*Sight.*—The starch should be quite white, or with the very slightest tinge of yellow; any decided yellow indicates commencing changes; the amount of bran should not be great.

*Touch.*—There should be no lumps, or, if there are, they should at once break down on slight pressure; there must be no grittiness, which shows that the starch grains are changing, and adhering too strongly to each other, and will give an acid bread. There should, however, be a certain amount of adhesion when a handful of flour is compressed, and if thrown against a wall or board some of the flour should adhere. Whan made into a paste with water, the dough must be coherent, and draw out easily into strings.

*Taste.*—The taste must not be acid, though the best flour is slightly acid to test-paper. An acid taste, showing lactic or acetic acids, is sure to give an acid bread.

*Smell.*—There must be no smell of fermentation or mouldiness.

Age of flour is shown by colour, grittiness, and acidity.

#### *Chemical Examination.*

It is seldom that a medical officer will be able to go through a complete examination, but he should always determine the following points:—

1. *Amount of Water.*—Weigh 1 gramme, spread it out on a dish, and dry either by a water bath or in a hot-air bath or oven, the temperature not being allowed to go above 200°. The flour must not be at all burnt or much darkened in colour. Weigh directly the flour is cold; the loss is the percentage of water.

The range of water is from 10 (in the best dried flours) to 18 in the worst. The more water the greater liability of change in the flour, and, of course, the less is the amount of nutriment purchased in a given weight. If, then, the water be over 18 per cent., the flour should be rejected; if over 16, it should be unfavourably spoken of.

2. *Amount of Gluten.*—Weigh 10 grammes (or 100 grains, if there are no gramme weights), and mix, by means of a glass rod, with a little water, so as to make a well-mixed dough; let it stand for quarter of an hour in an evaporating dish; then pour a little water on it; work it about with the rod,

and carefully wash off the starch; pour off from time to time the starch water into another vessel. After a time, the gluten becomes so coherent, that it may be taken in the fingers and worked about in water, the water being from time to time poured off till it comes off quite colourless. If there is not time to dry the gluten, then weigh; the dry gluten is rather more than one-third the weight of the moist; 1 to 2·9 is the usual proportion; therefore divide the weight of the moist gluten by 2·9. If there be time, dry the gluten thoroughly, and weigh it. This is best done by spreading it out on a crucible lid and drying it in the bath. The dry gluten ranges from 8 to 12 per cent.; flour should be rejected in which it falls below 8. If there is much bran, it often apparently increases the amount of gluten by adhering to it, and should be separated if possible; in fact, the gluten, as thus obtained, is never pure, but always contains some bran, starch, and fat. The gluten should be able to be drawn out into long threads; the more extensible it is the better. It is always well to make two determinations of gluten, especially if there is any disputed question of quality.[*]

3. *Amount of Ash.*—Take 10 grammes,[†] put into a porcelain or platinum crucible, and incinerate to white ash. Weigh. The ash should not be more than 2 per cent., or probably some mineral substances have been added; it should not be less than ·8, or the flour is too poor in salts.

The incineration of the flour requires a crucible and gas. It is difficult to do it over a spirit lamp, as it takes a long time. A small charcoal fire is probably the best plan when gas appliances are wanting.

If the ash be more than 2 per cent., add hydrochloric acid, and see if there be effervescence (magnesium or calcium carbonate). Dissolve, and test with oxalate of ammonium, and then for magnesia, in the same way as in water. As flour contains both lime and magnesia, to prove adulteration, the precise amount of lime and magnesia must be determined by weighing the incinerated calcium oxalate, or the magnesium pyrophosphate.

If there is no effervescence, add water, and test for sulphuric acid and lime, to see if calcium sulphate (plaster of Paris) has been added. In normal flour the amount of sulphuric acid is very small.

Notice, also, if the ash be red (from iron). If clay has been added, it will be left undissolved by acids and water.

If magnesium carbonate has been added, the ash is light, and porous and bulky (Hassall).

An easy mode of detecting large quantities of added mineral substances is given by Redtenbacher; the flour is strongly shaken with chloroform; the flour floats, while all foreign mineral substances fall. This is a very useful test.[‡]

If the water be small, the gluten large, and the salts in good quantity, the flour is good, supposing nothing is detected on microscopical examination. But in all cases it is well, if time can be spared, to have a loaf made.

*Practical Test by Baking.*—Make a loaf, and see if it is acid when fresh, and how soon it becomes so; if the colour is good, and the rising satisfactory.

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[*] Mr. Wanklyn has proposed to utilise the albuminoid ammonia process for determining gluten, reckoning that 100 parts of flour yield 1·2 of ammonia.

[†] If only a small crucible be employed a smaller quantity should be taken, as it is difficult to incinerate; with a moderately good balance, 2 or 3 grammes may be used.

[‡] The remaining ingredients can be determined, if necessary, from the starch water, but it is seldom necessary to do so. Allow the starch to subside, pour off the fluid, and wash the starch by decantation, then dry and weigh; take all the water and washings, evaporate to a small bulk, add a little nitric acid, and boil; albumen is thrown down; collect, wash, and weigh. Evaporate the whole of the remainder to dryness, and weigh (mixed dextrine and sugar).

Old and changing flour does not rise well, gives a yellowish colour to the bread, and speedily becomes acid. Excess of acidity can be detected by holding a piece of bread in the mouth for some time, as well as by test-paper.

*Test for Ergot.*—There is no very good test for ergot when it is ground up with the flour. Laneau's plan is to make a paste with a weak alkaline solution; to add dilute nitric acid to slight excess, and then alkali to neutralisation; a violet-red colour is said to be given if ergot is present, which becomes rosy-red when more nitric acid is added, and violet when alkali is added.

Wittstein considers this method imperfect, and prefers trusting to the peculiar odour of propylamine (herring-like smell), developed by liquor potassæ in ergoted flour. I have no experience of this point.

### *Microscopical Examination.*

This is especially directed to determine the relative amount of flour and bran, the presence of fungi or acari, or the fact of adulteration by other grains.

*Structure of the Wheat Grain.**—It is necessary to refer briefly to the structure of the grain of wheat, as this, of course, must be thoroughly understood.

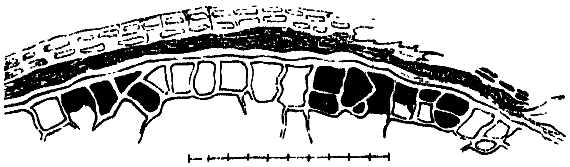

Fig. 30.—Transverse Section of Envelopes of Wheat. Scale 1000th of an inch.

There are four envelopes (some authors make three, others five or six—the outer coat being divided into two or three), surrounding a fine and very loose areolar tissue of cellulose filled with starch grains.

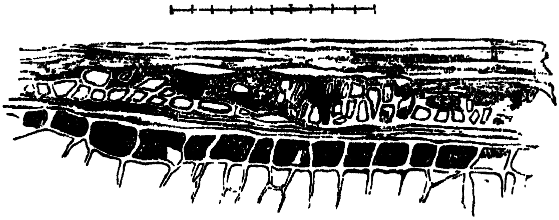

Fig. 31.—Envelopes of Wheat (longitudinal section). Scale 1000th of an inch.

*Envelopes of Wheat.*—The drawings show the coats *in situ*, cut transversely and longitudinally, also the separate coats. The outer coat is made up of two or three layers of long cells, with slightly beaded walls, running in the direction of the axis of the grain. The septa are straight or oblique, and, as will be seen, the cells differ in length and breadth. The size can be taken by the scale. The hairs are attached to this coat, and are prolongations, in fact, of the cells. In the finest flour the hairs and bits of this coat (as well of the other coats) can be found.

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* In examining wheat, or any other cereal grains, it is necessary to prepare them beforehand by soaking for some time in water. It will then be found easy to demonstrate the different structures. By means of a needle and a pair of fine forceps the different coats can be removed *seriatim*, sometimes quite separately, but generally more or less in combination. The only one that presents any difficulty is the third coat of wheat or barley, but generally it can be found accompanying the second or fourth coats. In the case of barley, the proper external envelope of the grain sometimes adheres to the interior of the husk, where it ought to be looked for in the event of its not being on the surface of the grain itself. After examining the separate coats, sections may be made of the whole grain, so as to see the structures *in situ*. The hairs are generally found in a bunch at the end of the grain. The starch grains are best demonstrated by picking out a little from the centre of the grain: mixed glycerine and water form the best medium for demonstration.

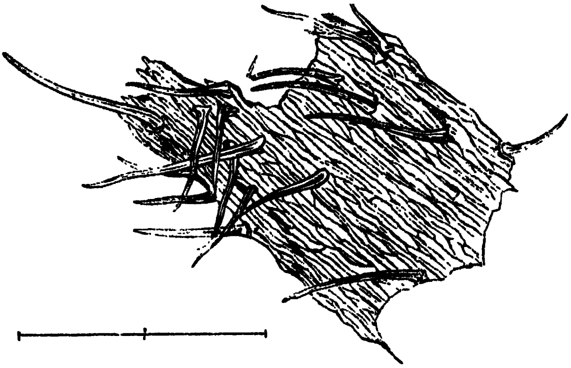

Fig. 32.—Outer Coat and Hairs of Wheat. Scale 100th of an inch.

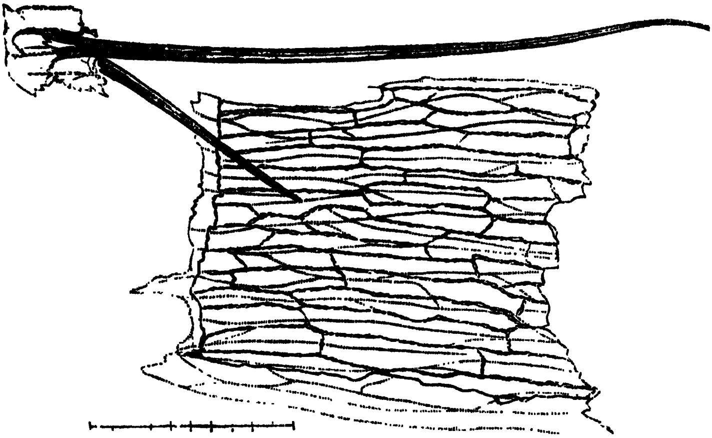

Fig. 33.—Outer Coat and Hairs of Wheat. Scale 1000th of an inch.

The second coat, counting from without, is composed of a layer of shorter cells, more regular in size, with slightly rounded ends and beaded walls, and lying at right angles to the first coat, or across the axis of the grain. It is impossible to mistake it. The third coat is a delicate diaphanous, almost hyaline membrane, so fine that its existence was formerly doubted. Dr Maddox, however, has distinctly shown it to have faint lines crossing each other diagonally as seen in the drawing, which may be cells. With a little care, it is very easily demonstrated. In the transverse section of the envelope it appears as a thin white line. Internal, again, to this coat what appears to be another coat can sometimes be made out; it is a very fine membrane, marked with widely separated curved lines, which look like the outlines of large round or oval cells. The internal or fourth coat, as it is usually called, is composed of one or two layers (in places) of rounded or squarish cells filled with a dark substance which can be emptied from the cells. When the cells are empty, they have a remote resemblance to the areolar tissue of the leguminosæ, and there is little doubt that from this cause adulteration with pea or bean has been sometimes improperly asserted.

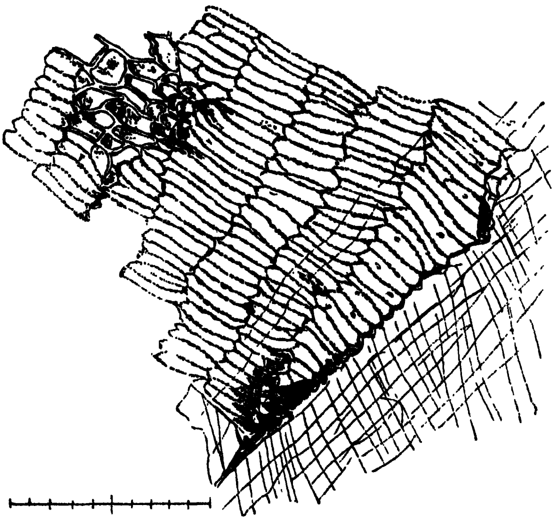

Fig. 34.—Second and Third Envelopes of Wheat. Scale 1000th of an inch.

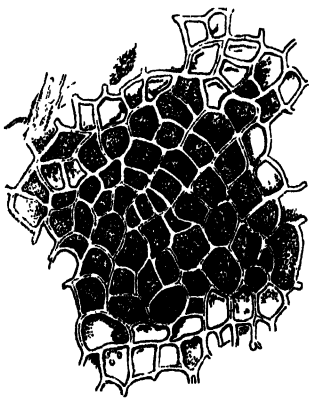

Fig. 35.—Fourth Envelope of Wheat. Scale 1000th of an inch.

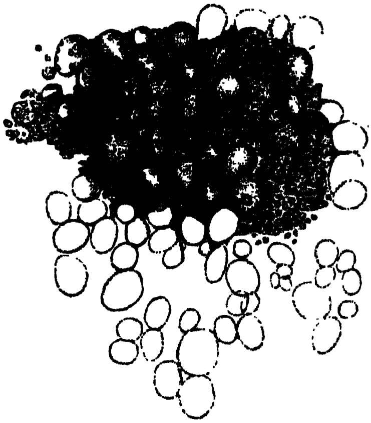

Fig. 36.—Fresh Starch-grains of Wheat (moistened × 360.

*The Starch Grains* of wheat are very variable in size, the smallest being almost mere points, the largest $\frac{1}{1000}$th of an inch in diameter or larger. In shape the smallest are round; the largest round, oval, or lenticular. It has been well noticed by Hassall that there is often a singular want of intermediate-sized grains. The hilum, when it can be seen, is central, the concentric lines are perceived with difficulty, and only in a small number; the edge of the grain is sometimes turned over so as to cause the appearance of a slight furrow or line along the grain. Very weak liquor potassæ causes little swellings; strong liquor potassæ bulges them out, and eventually destroys them. There is no difficulty in seeing if the pieces of envelopes are too numerous, but it should be remembered the best flour contains some.

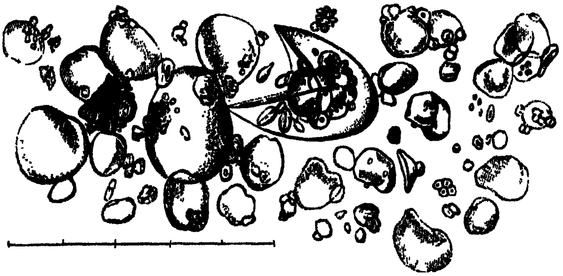

Fig. 37—Dried and then moistened Starch-grains of Wheat. Scale 1000th of an inch.

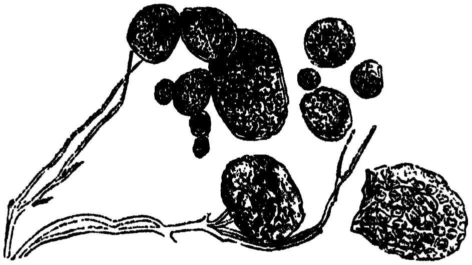

Fig. 38.—Diseased Flour (Puccinia).

### *Diseases of Flour.*

*Fungi.*—Several fungi are found in wheat-flour. The most common fungus is a species of Puccinia. It is easily recognised by its round dark sporangia, which are either contoured with a double line, or are covered with little projections. It is said not to be injurious by some, but this is very doubtful. The symptoms have not been well described.

The smut, or caries, is also a species of Puccinia; has large sporules, and gives a disagreeable smell to the flour, and a bluish colour to the bread. It is said to produce diarrhœa.

*Acarus.*—The *Acarus farinæ* is by no means uncommon in inferior flour, especially if it is damp. It does not necessarily indicate that leguminous seeds are present, as stated. It is no doubt introduced from the grain in the mill, as I have found it adhering to the grain itself. It is at once recognised. Portions of the skin are also sometimes found.

*Vibriones.*—These form for the most part in flour which has gone to extreme decomposition, and which is moist and becoming discoloured. They cannot be mistaken.

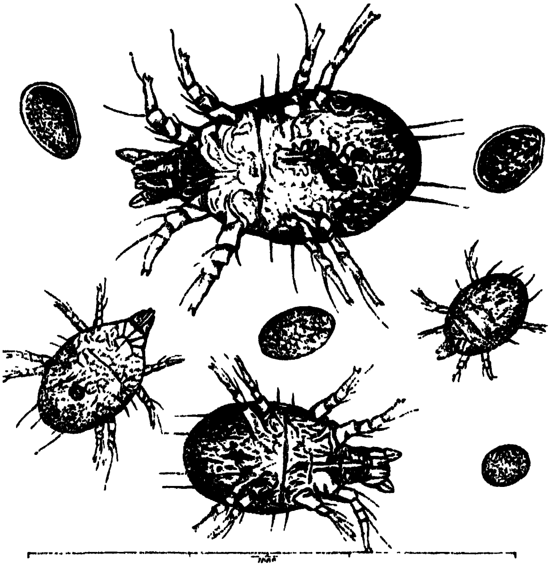

Fig. 39.—*Acarus farinæ* (× 85 diameters).—Mites found in flour alive. In the largest figures, the insects are considerably compressed, to show the powerful mandibles, and have each a ventral aspect. In the smallest and middle-sized insect, we have drawn the dorsal aspect; the former only possesses six legs, as before the first moult; several ova lie scattered in the field of view. It is unknown what office the capsular organs fulfil. They are well seen on each side of the largest figure.

The presence of Acari always shows that the flour is beginning to change. A single acarus may occasionally be found in good flour, but even one should be looked on with suspicion, and the flour should be afterwards frequently examined to see if they are increasing.

Fig. 40.
Weevil—Natural size.

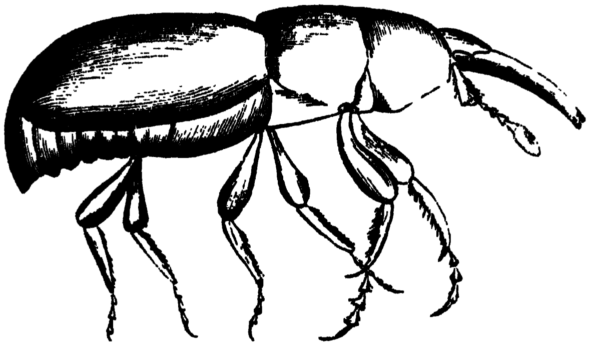

Fig. 41.—Weevil. Magnified 12 diameters.

*Weevil* (Calandra granaria).—The weevil is of course at once detected. It is by no means so common in flour as in corn.

*Ephestia.*—The larva of the moth, which feeds on cocoa (*Ephestia elutella*), has sometimes caused great ravages in flour and in biscuits. At Cork and Gibraltar many tons of biscuit have been rendered useless by this larva, which appears to have been introduced from the cocoa stored for the fleet.*

### *Adulterations of Wheat-Flour.*

At present there is very little adulteration of wheat-flour in this country, but with rising prices the case may be different. Abroad, adulteration is probably more common, and the medical officer must be prepared to investigate the point.

The chief adulterations are by the flour of other grains, viz. :—

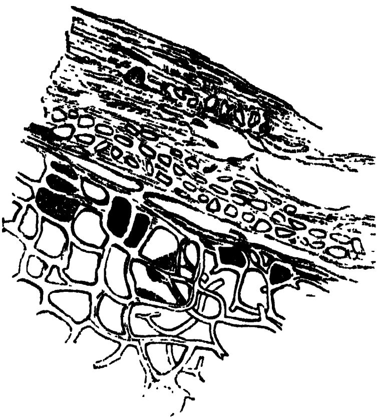

Fig. 42.—Barley—Longitudinal Section.
Scale is the same as that of the Starch-grains.

Barley,
Potato,
Beans and peas,
Maize,
Oat,
Rye,

Rice,
Buckwheat,
Millet,
Linseed,
Melampyrum,
Lolium, } in some countries,

other grains noticed farther on. All these are best detected by the microscope.

Other adulterations are by mineral substances, viz. :

Alum,
Gypsum,
Clay,

Powdered flint,
Calcium and magnesium carbonate.

These are best detected by chemical examination. (For the detection of alum, see the chapter on BREAD.)

*Detection of Barley.*—This is not easy, but can, with care, be often done.

*The envelopes of barley* are the same in number as those of wheat, but they are more delicate. The outer coat has three layers of cells ; the walls of the external layer are beautifully waved, but not beaded; the cells are smaller than those of the outer coat of wheat. The second coat, disposed of at right angles to the first, as in wheat, is like the second coat of wheat, except in being more delicate and not beaded. The third is hyaline and transparent, as in wheat. The fourth has the cells similar in shape to the corresponding wheat coat, but they are very much smaller, as may be seen on reference to the scale, and there are two, or often three, layers.

The *starch grains* of barley are very like the wheat, with a central hilum and obscure marking, but are on the whole smaller; some have thickened edges, instead of the thin edges of the wheat-starch grain, but it is very difficult, and sometimes impossible to distinguish them. It is therefore especially to the envelopes that we must attend.

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* Professor Huxley has kindly given me some interesting details. The larva of the *Ephestia elutella* (or "chocolate moth") is small, and is never more than half an inch long. The female moths fly at night in swarms, and lay their eggs on the biscuits or the puncheons which hold them. The larvæ are soon hatched, and by means of strong jaws and active legs scrape and bore their way through crevices; they eat the biscuit, and spoil more than they eat by spinning their webs over the biscuit. Cocoa stores swarm with the moths and larvæ, and they even penetrated into many parts of H.M.S. "Hercules."

After examining into the ravages caused by these larvæ in the biscuit at Gibraltar, Mr Huxley made the following suggestions :—

1. To have no cocoa stored in any place in which biscuits are manufactured.
2. To head up all biscuit puncheons as soon as they are full of the freshly-baked biscuit.
3. Coat puncheons with tar after they are headed up, or at least work lime wash well into all the joints and crevices.
4. Line the bread-rooms of ships with tin, so that if the Ephestia has got into a puncheon it may not get into the rest of the ship.
5. If other means fail, expose woodwork of puncheons to a heat of 200° Fahr. for two hours.

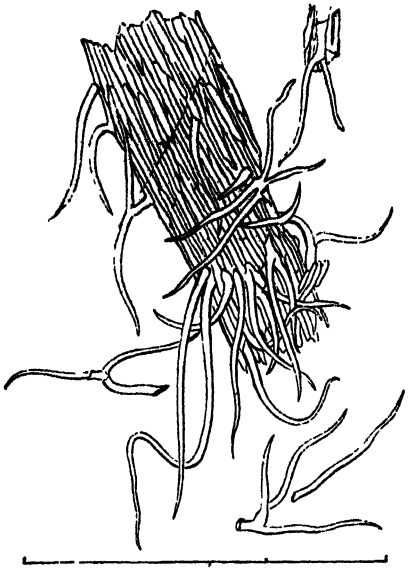


Fig. 43.
Outer Coat and Hairs of Barley (low power).

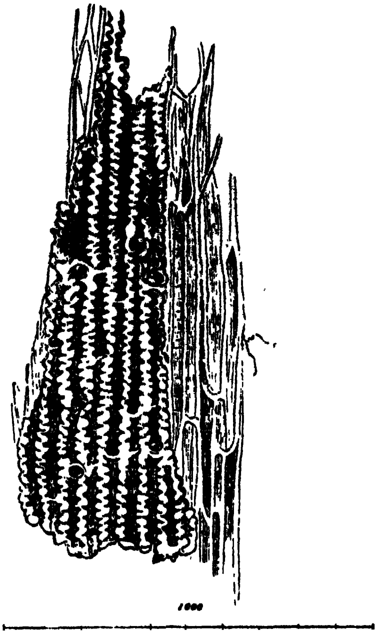


Fig. 44.
Outer Coat of Barley (higher power).

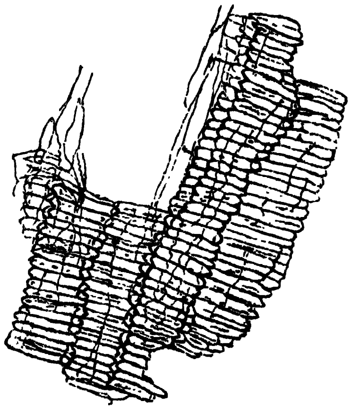


Fig. 45.—Barley (second and third coats).

*Detection of Potato Starch.*—This is a matter of no difficulty; the starch grains, instead of being round or oval, and with a central hilum and obscure rings, are pyriform, with an eccentric hilum placed at the smaller end, and with well-marked concentric rings. Weak liquor potassæ (1 drop of pharmacopœial liq. pot. to 10 of water) swells them out greatly after a time, while wheat-starch is little affected by this strength; if the strength is 1 to 3 (as in the figure), the swelling is very rapid.

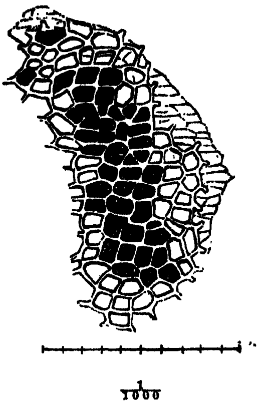


Fig. 46.—Barley (fourth coat).

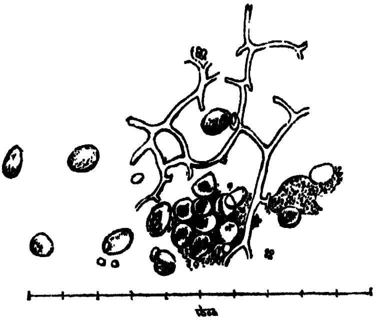


Fig. 47.—Barley (Starch-grains).

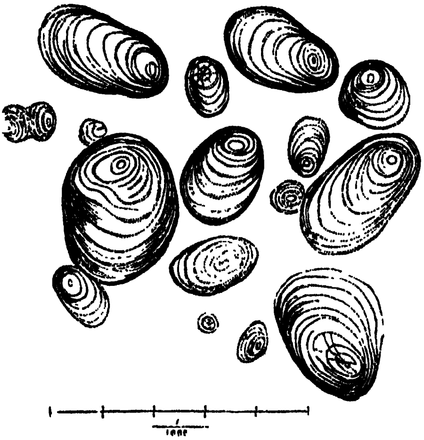


Fig. 48.—Potato Starch × 285. See also Plate of Starches.

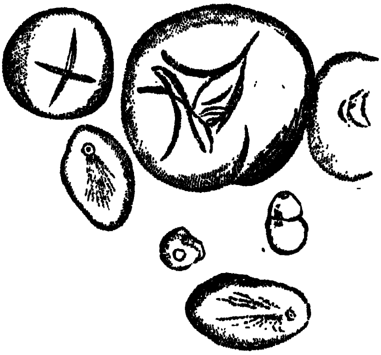


Fig. 49.—Medium and small-sized Potato starch-grains, treated with Liq. Pot. Ph. Lond. One-third part and × 285.

*Detection of Maize* (*Indian Corn*).—There are two envelopes; the outer being made up of seven or eight strata of cells; there is no transverse second coat, as in wheat; the internal coat consists of a single stratum of cells like the fourth of wheat, but less regular in shape and size. The cellulose, through the seed holding the starch in its meshes, forms a very characteristic structure, which on section looks like a pavement made of triangular or square pieces; the cells are filled with the starch-grains, which are very small, and compressed, so as to have facets. They are very different from the smooth, uncompressed round cells of wheat.

Bits of cellulose, with its peculiar angular markings, are always found if the wheat is adulterated with maize.

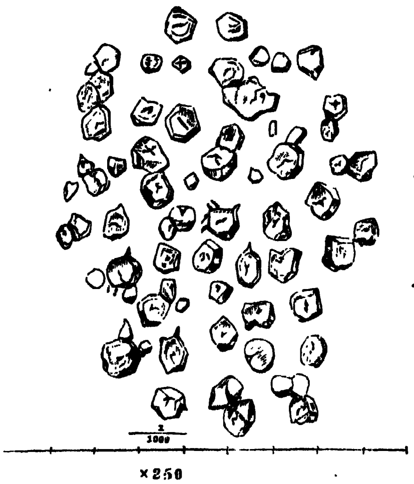
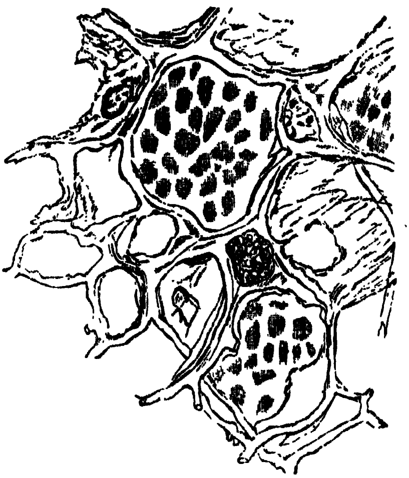


Fig. 50.—Indian-Corn Flour. See also Plate of Starches.



Cellulose of Indian Corn × 500, with markings from the starch-grains on the intercellular membrane.

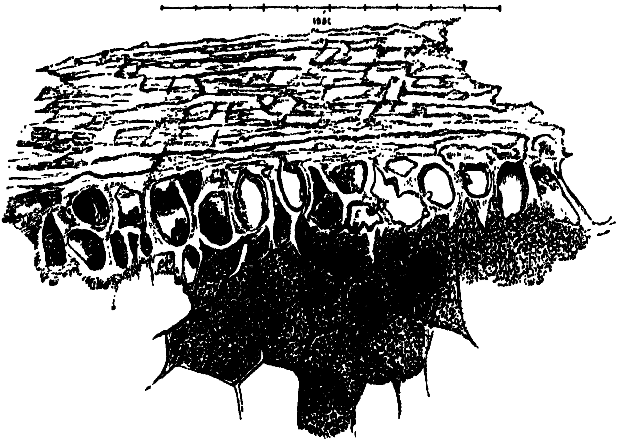


Fig. 51.—Longitudinal section of Coats of Indian Corn and Cellulose × 190.

*Detection of Bean and Pea.*—These adulterations are also at once discovered; the meshes of cellulose are very much larger than those of the fourth coat of wheat, with which it has sometimes been confounded, and the starch-grains are also quite different; they are oval or reniform, or with one end slightly larger; they have no clear hilum or rings, but many have a deep central longitudinal cleft running in the longer axis, and occupying two-thirds or three-fourths of the length, but never reaching completely to the end; this cleft is sometimes a line, sometimes almost a chasm, and occasionally secondary clefts abut upon it at parts of its course; sometimes, instead of a cleft, there is an irregular-shaped depression. If a little liquor potassæ be added, the cellulose is seen more clearly. Pea flour is never added to a greater extent than 4 per cent., as it makes the bread heavy and dark. If the flour be mixed with a little boiling water, the smell of the pea or bean is perceptible.*

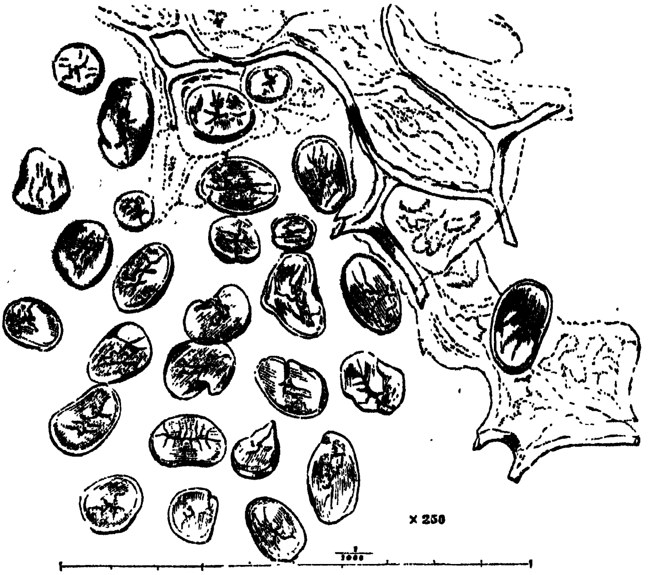


Fig. 52.—Bean Starch.

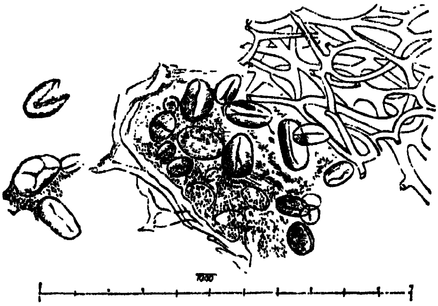


Fig. 53.—Pea Flour.

*Detection of Oat.*—There are two or three envelopes; the outer longitudinal cells; the second obliquely transverse, and not very clearly seen; the cells are wanting in parts, or pass into the cells of the third coat; the third a layer, usually single, of cells like wheat. The husk must be detached before the envelopes are looked for. The starch-cells are small, many-sided, and cohere into composite round bodies, which are very characteristic, and which can be broken down into the separate grains by pressure. A high power is the best for this. The oat starch does not polarise light. There is no difficulty in the detection of the starch grains.

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* A chemical test has been given by Donné to detect admixture of garden beans. The powder is smeared round the inside of a small vessel; at the bottom of the vessel seven or eight drops of nitric acid are allowed to fall, and are evaporated by means of a lamp, the vessel being partly covered to prevent too rapid evaporation; when the flour has partly become brown, a few drops of ammonia are put in the capsule, and left to spontaneous evaporation. A beautiful red colour forms about the centre of the flour where the action of the nitric acid has been neither too strong nor too feeble. A lens will pick out at once the red points of the bean flour. This reaction must be marked to be of any value.* Several other tests have been given, but are imperfect and really unnecessary, for the microscopic characters are sufficient.

* Stas has given facts which appear to greatly lessen its value.—Squillier, *Des Subsist. Mil.* p. 93.

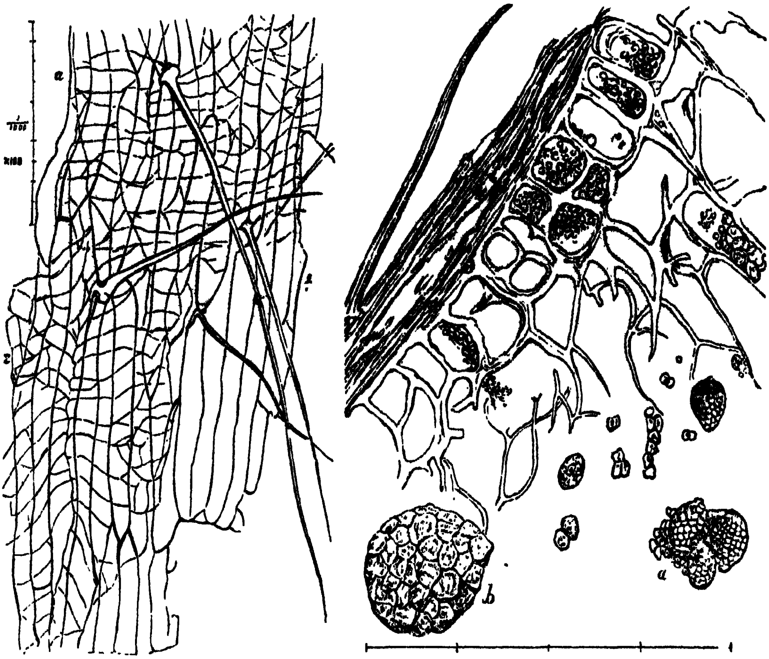


Fig. 54.—White Oat—Long. sect., 2d and 3d coats not separable. *a* Compound grains × 100, *b* One do. × 500.

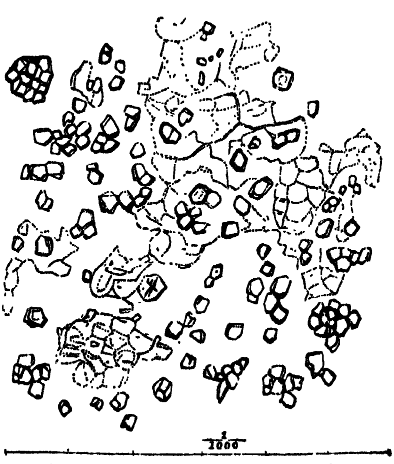
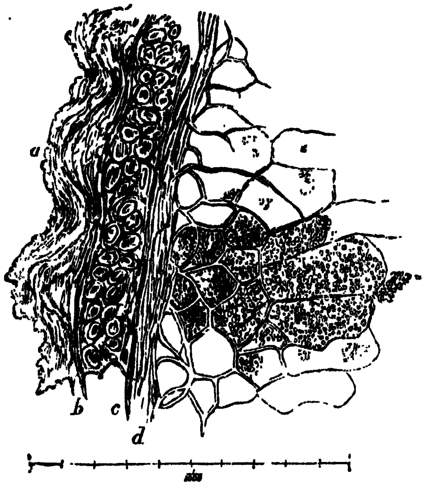


Fig. 55.—Ground Rice Flour × 350;

*Detection of Rice.*—The husk of rice is very peculiar; on the outer coat are numerous siliceous granules, arranged in longitudinal and transverse ridges (figs. 56 and 57) (*a*). There are numerous hairs, some of which are seated over stomata. Below this is a membrane of transverse and longitudinal rough-edged fibres (*b c*), while below these again is a fine membrane of transverse angular cells (*d*), covering a very delicate membrane of large cells. The starch corpuscles are very small, (fig. 55); angular under low powers; under high powers they are seen to be facetted and compressed. They cannot be mistaken for the round cells of wheat, but may be confounded with oat starch, from which, however, they are distinguished by the absence of the compound cells or glomeruli. Their shape is also a little like maize, but they are very much smaller.



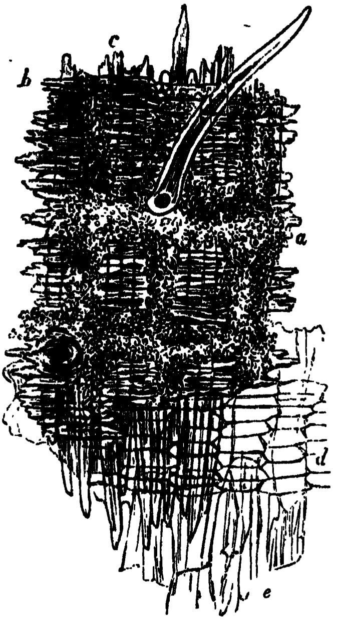


Fig. 56.—Rice × 170. Fig. 57.—Rice × 178.

Fig. 56. Transverse section of the Husk of Rice, . . . . . . . . } × 170.
Fig. 57. Appearance of Husk as seen in a transparent medium of glycerine and gum, }
*a*, Siliceous granules, arranged in longitudinal and transverse ridges, perforated by openings—stomata, some having hairs seated over them. *b c*, Transverse and longitudinal, brittle, rough-edged fibres. *d*, A fine membrane of transverse angular cells; these overlie a very delicate membrane of large cells *e*.

*Detection of Rye.*—The envelopes are very like those of wheat, and can perhaps be hardly distinguished. The recent starch grains are also extremely like those of wheat, but the older and drier grains have sometimes a peculiar rayed hilum. I have seen this, however, in very old wheat, but never to the same extent as in rye.

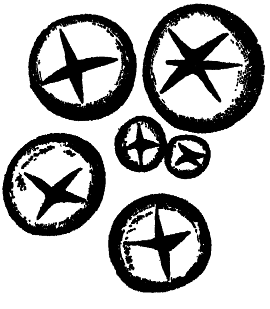


Fig. 58.—Rye-starch, with rayed hilum (after Hassall) × 420.

Rye, if in any quantity, is discovered by baking; it makes a dark, acid bread.

*Linseed* is not a common adulterant. The envelopes are peculiar: the external is made up of hexagonal cells, containing oil; the second of round cells; the third of fibres; and the fourth of angular cells, containing a dark reddish colouring matter.

*Buckwheat* (Polygonum Fagopyrum, or Fagopyrum esculentum).—Like rye, this is only likely to be found in wheat coming from the Baltic. The drawing sufficiently shows the texture of the envelopes, which is very complicated. The starch-grains are small and round, and adhere together in masses. Under a high power there are indications of concentric rings. Bread made with this grain has a darkish, somewhat violet, colour.

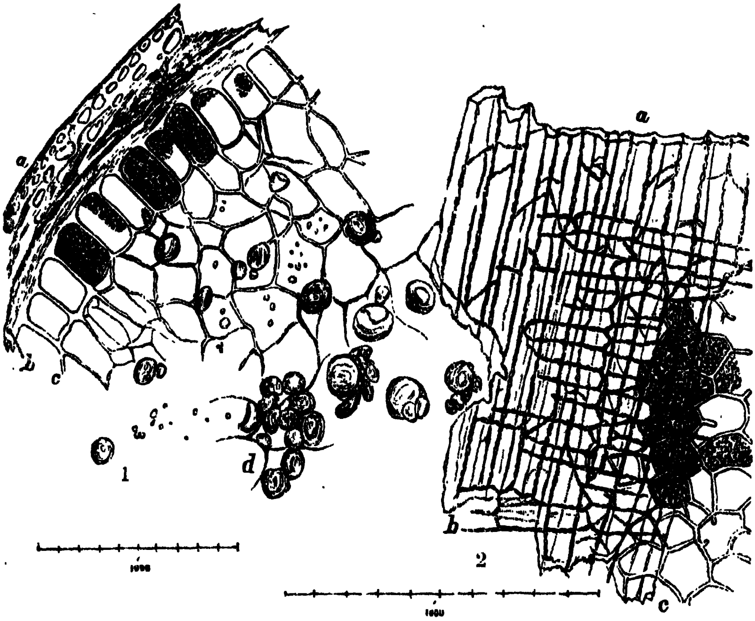


Fig. 59.—Rye—1. Transverse section of Testa, &c., × 108 ; 2. Coats *in situ* from without, × 170. *a*, External ; *b*, Middle ; *c*, Internal coat ; *d*, Starch-grains, × 108.

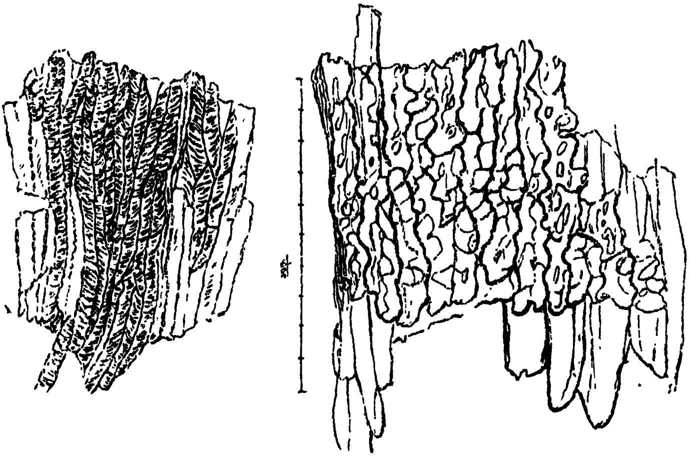


Fig. 60.—Outer coat of Buckwheat, apparently of irregular and interlacing fibrospiral cells, separable by boiling the testa and macerating it. Outside these cells is a very thin and delicate membrane, retaining the marks of attachment of the spiral cells, × 170.

Internal coats. The most internal is composed of cells with an irregular waved outline, and longitudinal cells over the starch-cells × 170.

*Millet.*—In India, Egypt, China, and West Coast of Africa, millet of some kind is likely to be an adulteration. Dr Maddox's drawing (page 239) shows the beautiful structure of the envelopes, which could not be confounded with those of wheat. The starch-grains are very small, round, and tolerably uniform in size.

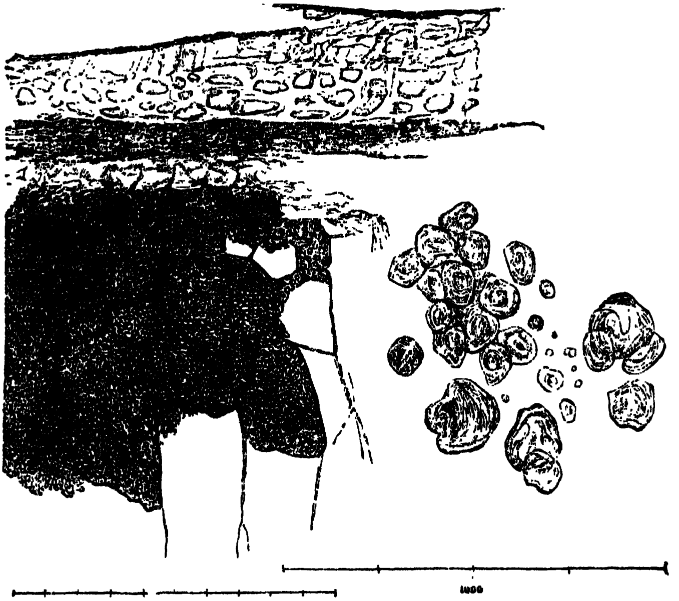


Fig. 61.—Buckwheat—Transverse section of outer, middle, and internal coats, with cellulose containing starch grains, . . . } ×170. Starch-grains × 500

*Melampyrum arvense* and other species (Purple cow-wheat—*Scrophulariaceæ*).—This has occasionally been mixed with flour; it is not injurious, but gives the bread (not the flour) a peculiar smoky violet or bluish-violet tint. This depends on a colouring matter in the seed, which, when warmed with acid, gives the violet colour.*

*Trifolium arvense* (Trefoil—*Leguminosæ*).—This also gives the bread a red violet colour. It is not known to be injurious.

*Rhinanthus major* and *crista-galli* (Yellow-rattle—*Scrophulariaceæ*) gives bread a bluish-black colour, a moist sticky feel, and a disagreeable sweet taste. It is not injurious. *Onobrychis sativa* (Sainfoin—*Leguminosæ*) has also been used.

*Lolium temulentum* (Rye-grass—*Gramineæ*. Other species may be used.)—This gives the bread no colour, but produces narcotic symptoms, vertigo, hallucinations, delirium, convulsions, and paralysis.† Pellischek states that these symptoms do not occur if the grain be dried in an oven before baking, or if the bread is left for some days before being used. The detection of the lolium is best effected by means of alcohol, which gives a greenish solution with a disagreeable repulsive taste, and on evaporation a resinous yellow-green disagreeable extract is left. Pure flour gives with alcohol only a clean straw-coloured solution, with an agreeable taste (Pellischek).

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* Pellischek, Schmidt's Jahrb. 1863, No. 3, p. 287.

† The peculiar symptoms produced by the *Lolium temulentum*, or bearded Darnel, were well known to the ancients. Pereira states that the first symptoms are gastro-intestinal, such as vomiting and colic, and then cerebro-spinal symptoms come on, viz., headache, giddiness, tinnitus, confusion of sight, dilated pupils, delirium, trembling, and paralysis (Elements of Materia Medica, 1850, vol. ii. p. 977). The same effects are produced on animals. Pereira states that he did not succeed in obtaining the chemical test noted above, viz., the green alcoholic solution and the yellow resin on evaporation. Hassall figures the starch-grains of the lolium as small and something like rice; fifty or sixty may adhere together and form a compound

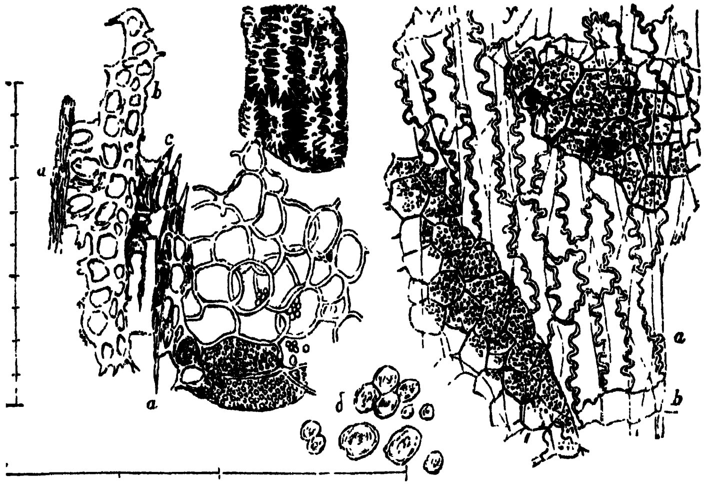

Fig. 62.—Millet Seed—*a*, Transverse section of Testa coats, seen from inside; *a*, Outer; *b*, Middle; *c*, Inner coat × 170; *δ*, Starch-grains × 500. Scale 1-1000th inch.

*Bromus* or *Serrafalcus* (Brome-grass—*Gramineæ*; different species—*Arvensis* or *Secalinus*).—Pellischek states that the seeds of this plant give the bread a dark colour, and make it indigestible. It is probably a most uncommon adulteration.

It will be found that when mixed with flour, the microscope will detect

grain not very unlike the oat. The envelopes are tolerably distinctive; the cells of the outer coat are made up of a single layer, and are disposed transversely instead of longitudinally. The second coat is in two layers, and the cells have a vertical arrangement. The third coat is like the inner coat of wheat. This account is taken from Hassall. I have not examined this grain myself.

It is not very likely that any other grains except those mentioned in the text will be mixed with wheat flour. The seeds of the Peruvian food, the *Chenopodium Quinoa* have not to my knowledge been used as a falsification. The starch-grain of the Quinoa are said to be the smallest known. It may be worth remarking that this seed is very rich in salts (2·4 per cent.), and particularly so in iron (·75 per cent.); indeed it is, I believe, the richest in iron of any vegetable. It is possible that it might be a useful food in some cases of illness. It is fairly nutritious and digestible.

The starch-grains of the acorn, which might perhaps be added in times of great scarcity, would be immediately detected, as they have a very characteristic central depression, and are also quite different in shape from the flat, round, smooth starch-cells of the wheat and barley.

The microscope alone will seldom be able to recognise added mineral matters, because these are not in very large quantity, and even in the best flour some small amount of mineral substances, derived either from the outer coats or from the mill, can be seen. The addition of mineral matters is best determined chemically, but if it is attempted with the microscope, the gluten should be separated first; the starch should then be well mixed with water, and then allowed to subside in a conical vessel. In the lower part of the vessel the mineral matters will be found in greatest amount. If a little iodine be added to distinguish the starch-cells, the microscope may then recognise perhaps an unusual quantity of round or perhaps angular particles. If they are bone or chalk, acetic acid will dissolve them; if clay, the acid will not affect them; or the sediment, when chloroform is mixed with flour, may be examined.

readily many of these substances. Detection is often very difficult when the flour is made into bread, and therefore, whenever from the bread there is any cause of suspicion, means should be taken to obtain some of the flour.

*Cones flour.*—A flour obtained from Revet wheat is used by bakers for dusting their troughs. Hassall has found this Cones flour to be greatly adulterated with rice,* maize, beans, rye, and barley. Sometimes Cones flour is mixed with good flour. All these impurities have been already described.

### *Cooking of Flour.*

The effect of heat is to coagulate the albumen, and to transform some of the starch into dextrin. Substances are also added to the bread to cause a further transformation of the starch.

*Cakes.*—The unfermented cakes† are simply made with water and salt. As they are very readily made, are agreeable to taste, and nutritious, it is very desirable to teach every soldier to make them; so that in war, when bread is not procurable, he may not be confined altogether to biscuit. The Australian "damper" is simply made by digging a hole in the ground, filling it with a wood fire, and, when the fire has thoroughly burnt up, removing it, placing the dough on a large stone, covering it with a tin plate, and heaping the hot ashes round and over it. In a campaign, every soldier, if he could get flour and wood, would soon learn to bake a cake for himself. The only point of manipulation which requires practice is not to have the heat too great; if it be above 212° too much of the starch is changed into dextrin, and the cake is tough. Exposed to greater heat, and well dried, the unfermented cakes become biscuit.

Maccaroni is flour from a hard Italian grain, moistened with water, and pressed through a number of small openings, while at the same time heat is applied. As it is very nutritious in small bulk, and keeps well, it would be a good food for soldiers in war if its cost could be lessened.

## SUB-SECTION III.—BISCUIT.‡

To make biscuit, flour is often taken with little or no bran (on account of the hygroscopic properties of bran); but bran is also sometimes used; no salt is added. The simplest biscuits are merely flour and water. Some biscuits are made with milk, eggs, &c.

*Choice of Bicuit.*—Biscuit should be well baked, but not burnt; of a light yellow colour, and should float in water; when struck, it should give a ringing sound; and a piece put into the mouth should thoroughly soften down. It should be free from weevils, which are easily seen. (See page 230 for a notice of the Ephestia.)

*Advantages as a Diet.*—As it contains little water, and, bulk for bulk, is more nutritious than bread, three-fourths of a pound are usually taken to equal 1 lb of bread. Its bulk is small, and it is easily transported.

*Disadvantages.*—Like flour, it is deficient in fat. After a time, it seems difficult of digestion. Perhaps the want of variety is objectionable; but certain it is, that men do not thrive well upon it for long periods. In war, it

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* Several samples I have examined contained nothing but rice. This is sometimes sold as "Rice Cones." (F. de C.)

† The Chupatty of India.

‡ Composition of Biscuit:—

| | | | |
|---|---|---|---|
| Water, | 8 to 12 | Sugar, | 1·9 |
| Nitrogenous substances, | 15 | Fat, | 1·8 |
| Dextrin, | 3·8 | Starch, | 72 to 75 |

has always been a rule with the best English army surgeons, for more than a century, to issue bread as much as possible, and to use biscuit only in cases where it cannot be avoided.

## SUB-SECTION IV.—BREAD.[*]

If carbonic acid gas is any way formed in or forced into the interior of dough, so as to divide the dough into a number of little cavities, bread is made.

There are three kinds of bread :—

1. Carbonic acid is disengaged by a fermentative process, caused by yeast or leaven. During the baking a certain amount of performed sugar yields carbonic acid; a portion of starch is converted into dextrin and sugar, and also yields carbonic acid; a little lactic and butyric acids, and extractive matters are formed. It is of importance to prevent this change from going too far; and herein is one of the arts of the baker; and it is partly to prevent this that alum is added, which has the property of arresting the change.

In making bread, the proportions are 20 ℔ of flour; 8 to 12 ℔ of tepid water; 4 oz. of yeast, to which a little potato is added, and 1½ to 2 oz. of salt; 280 ℔ of flour (1 sack) will give from 90 to 105 4-℔ loaves; or 100 ℔ of flour will make from 129 to 150 ℔ of bread. If there is 14 per cent. of water in the flour, the bread will contain in the former case 33·1 per cent., and in the latter, 42·7 per cent. If 100 ℔ of flour contain 14 per cent. of water, and make 141½ ℔ of bread, the bread will contain 40 per cent. of water; the baker always endeavours to combine as much water as he can so as to get more loaves. 6½ ℔ of dough yield 6 ℔ of bread. Machines are now generally used for mixing the dough (Stevens' Machine).

2. Carbonic acid is disengaged by mixing sodium or ammonium carbonate with the dough, and adding hydrochloric, tartaric, phosphoric, or citric acids. Baking powders are compounds of these substances.

3. Carbonic acid is forced through the dough by pressure (Dauglish's patent aerated bread). This process has the great advantage of rendering it impossible that the conversion of starch into dextrin, sugar, and lactic acid shall go too far. About 20 cubic feet of carbonic acid (derived from chalk and sulphuric acid), are used for 280 ℔ of flour; and about 11 cubic feet are actually incorporated with the flour (Odling).

### *Advantages of Bread as an Article of Diet.*

It is hardly necessary to mention these. The great amount of nitrogenous

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[*] Composition of Bread:—

| | Water. | Nitrogenous Substances. | Fat. | Starches, &c. |
|---|---|---|---|---|
| English Baker's Bread:— | | | | |
| Maximum nutriment, . . | 33 | 8·57 | 1·5 | 56·93 |
| Minimum nutriment, . . | 44 | 6·93 | 1 | 48·07 |
| French Commissariat:— | | | | |
| Old formula, . . . | 41 | 7·2 | 1·5 | 47 |
| New formula, . . . | 35 | 7·9 | 1·5 | 52·6 |
| Austrian Commissariat, . . | 45·50 | 6·2 | 1·4 | 46 |

The nitrogen in 100 parts of dry bread, in eleven different armies (examined by Poggiale), varied from 2·26 per cent. (French) to 1·12 per cent. (Prussian). In the usual English military hospital bread it is from ·9 to 1·2 per cent. of the undried bread, or 1·7 per cent. of dried bread. According to Reichenbach, the crust contains a substance (assamar), which has an influence in retarding tissue metamorphosis.

matters and starch it shares with flour; the nitrogenous substance is to the carboniferous as 1 to 6·3 (Forbes Watson, Odling). It therefore requires more nitrogen for a perfect food. The process of baking renders it more digestible than flour. No satiety attends its use, although it may be always made in the same way; this is probably owing to the great variety of its components.

*Disadvantages.*—It is poor in fat and some salts, especially in the case of the finest flour freed from the internal envelope. Therefore we see that the practice of using fat with it (butter for the rich, fat bacon for the poor man) is extremely common. As to the relative advantages of the three methods of making bread, the last (aeration by carbonic acid) is said to have the advantage of making white bread, though the inner envelopes are left; of not causing any loss of starch, or permitting the change to go too far; of not containing any unwholesome yeast. The system of making bread with yeast has been objected to on the ground that bad yeast is often used; the fermentative changes go on in the stomach, much carbonic acid gas is disengaged, and dyspepsia, flatulence, and unpleasant sensations, such as heart-burn, are produced. There is no doubt that badly prepared bread gives rise to these symptoms, though whether this is owing to bad yeast is, I think, uncertain. The second method yields a wholesome bread, but is too expensive for common use, and it has also been pointed out that the hydrochloric acid of commerce always contains arsenic. The amount would be too small to be hurtful, but might be of medico-legal consequence.

### *Special points about Making of Bread.*

Bread may be of bad colour—rather yellowish, from old flour; from grown flour (in which case the changes in the starch have generally gone on to a considerable extent, and the bread contains more sugar than usual, and does not rise well), and perhaps from bad yeast. The colour given by admixture of bran must not be confounded with yellowness of this kind.

Bread is also dark coloured from admixture of other grains, as already noticed under flour (rye, buckwheat, melampyrum, sainfoin, &c.) Bread may be acid, from bad flour giving rise to an excess of lactic and perhaps acetic acids, or, it is said, from bad yeast. In finding the cause of acidity in bread, look first to the flour, which may be old, and a little discoloured, and too acid; if nothing can be made out, examine the yeast, and change the source of supply; then look to the vessels in which the dough is kneaded, and to the water. Enforce great cleanliness on the part of the men who make up the dough. In India bread becomes sour from bad cleaning of the flour. Dr Godwin, R.A.,* states that at Bareilly the wheat was imperfectly ground in small hand-mills; it was then separated by shifting into four portions, viz., bran; "attar," which corresponds to pollards; "soojie," which consists of gluten and starch; and "maida," which is nearly all starch. The soojie, from imperfect grinding, is granulated, and chiefly used for bread, a small portion only of maida being mixed with it. To cleanse the wheat before grinding it, it was washed and then dried in heaps in the sun; this caused fermentation and a rapid development of acidity. The heaps of corn were quite hot to the feel. A very acid bread was given, but when the wheat was not thus washed it yielded a good bread.

Bread is heavy and sodden from bad yeast fermenting too rapidly, or when the fermentation has not taken place (cold weather, bad water, or some other cause, will sometimes hinder it), or when the wheat is grown; when too little or too much heat has been employed. It is said, also, that if the flour has been dried at too great a heat (above 200°), the gluten is altered, and the bread does not rise well. It is bitter from bitter yeast.

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* Army Medical Report, vol. vii. p. 451.

It becomes mouldy rapidly when it contains an excess of water.

Rice is used as an addition because it is cheaper; it retains water, and therefore the bread is heavier. Rice bread (if 25 per cent. of rice be added) is heavier, of closer texture, and less filled with cavities. Potatoes are sometimes added, but are generally used only in small quantity with the yeast.

Alum is added to stop an excess of fermentation, when the altering gluten or cerealin acts too much on the starch, and it also whitens the bread; it does not increase the amount of water; it enables bread to be made from flour which otherwise could not be used. Sulphates of copper and of zinc, in very small amount, are sometimes employed for the same purpose.

For acid flour, lime water is used instead of pure water; lime water has this advantage that, while it does not check the fermentation of yeast, it hinders the action of diastase on starch. It must be caustic lime water, and not chalk and water as sometimes is the case.

After being taken from the oven bread begins to lose weight.* The 4-℔ loaf loses,—

| | |
|---|---|
| In the first 24 hours, | 1¾ ounce. |
| In 48 „ | 5 „ |
| „ 60 „ | 7 „ |
| „ 70 „ | 8¾ „ |

But this is merely an average, and is altered by amount of crust, temperature, and movement of air.

Loaves are generally weighed when hot, and that is considered to be their weight. In the Austrian army, a loss of 2·9 per cent. in four days is permitted.

When loaves become stale they can be rebaked, and then taste quite fresh for twenty-four hours; after that they rapidly change.

Old biscuit also, mixed with water, can be rebaked, and becomes palatable.

In the French army different kinds of bread are used:† ordinary bread; biscuited bread; bread half biscuited; bread one quarter biscuited; hospital bread. The "Pain biscuité" is used only on service; it is baked more firmly than ordinary bread.

| | |
|---|---|
| Pain de munition ordinaire keeps | 5 days in summer and 8 in winter. |
| „ au quart biscuité „ | 10 to 15 days. |
| „ demi „ „ | 20 to 30 „ |
| „ biscuité „ | 40 to 50 „ |

The French munition loaf weighs 1·5 kilogrammes (3·3 ℔ avoir.), and contains two rations of 760 grammes (each 1·65 ℔). The ration of biscuit is 550 grammes (1·2 ℔).

It would be useful to adopt the practice of strongly baked bread in our army; it is a good substitute for biscuit.

*Compressed Bread.*—(See Concentrated Foods.)

### *Examination of Bread.*

There is, perhaps, no article on which the medical officer is more often called to give an opinion.

*General Characters.*—There should be a due proportion, not less than 30 per cent., of crust; the external surface should be well baked, not burnt; the crumb should be permeated with small regular cavities; no parts should be heavy, and without these little cells; the partitions between the cavities should not be tough; the colour should be white or brownish from admixture of bran; the taste not acid, even when held in the mouth. If the bread is acid the flour is bad, or leaven has been used; if the colour changes soon, and fungi form, the bread is too moist; if sodden and heavy, the flour is bad, or the baking is in fault; the heat may have been too great, or the sponge badly set.

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* For some recent experiments on this point, see Report on Hygiene, Army Medical Reports, vol. xviii.

† Code des Officiers de Santé, 1863.

*Chemical Examination.*—This is conducted chiefly to ascertain the amount of water, acidity, and the presence of alum or sulphate of copper.

*Water.*—Take a weighed quantity (say 10 grammes) of crumb, and dry in a water bath; powder, and then dry again in a hot-air bath or oven, and weigh; the water should not be more than 45 per cent.; if more, the bread is *pro tanto* less nutritious, and is liable to become sooner mouldy.

*Acidity.*—This can be determined by a standard alkaline solution. (See Beer.) At present few observations have been made on this point, but it may be important as indicating bad flour. In good bread the acidity on first baking is very trifling; it increases slightly for five or six days.[*]

*Alum.*—The determination of the presence of alum is not difficult, but the quantitative analysis is necessary, since it has been shown by Wanklyn that unalumed bread may contain an appreciable amount. Many processes have been proposed,[†] some of which are merely modifications of each other. The following seems the most simple:—

*1st part.*—Take at least ½ ℔ of crumb, put in a mortar, and soak it well in pure cold water; filter, and get as clear a fluid as possible; add a few drops of hydrochloric acid, and then chloride of barium. If there is no precipitate no alum can have been added, and the process need not be proceeded with. If there is a slight precipitate, it may be accounted for by sulphate of lime or magnesia in the water added, or of sulphate of magnesia in the salt, or by the slight amount of sulphuric acid naturally existing in the grain, or added during the grinding. Perhaps the medical officer will know whether the water or the salt contains sulphates, and if so, the absence of alum may be inferred. If there be a large precipitate, the presence of alum is probable, but is not certain, and the process must be continued.

*2d part.*—Dupre's process, as modified by Wanklyn, seems on the whole the simplest and least liable to error, as it gets rid of one great source of fallacy, namely, the presence of alumina in the liquor potassæ, which reagent is not required. The process is as follows:—Take 100 grammes (= 3½ ounces) of bread; incinerate for 4 or 5 hours in a platinum dish to a grey ash; weigh (the ash should not sensibly exceed 2 grammes); moisten with 3 C.C. of pure hydrochloric acid to separate silica; add 20 to 30 C.C. of distilled water, boil, filter; wash the filter well with boiling water; add to the filtrate, which contains the phosphates of calcium, magnesium, aluminium, and iron, 5 C.C. of liquor ammoniæ (sp. gr. 880), which causes a precipitate of these phosphates; then add gradually 20 C.C. of strong acetic acid, which partially clears the fluid by dissolving the phosphates of calcium and magnesium; boil and filter. The undissolved part is a mixture of phosphate of aluminium and phosphate of iron; wash, precipitate well with boiling water, dry, ignite, and weigh.

The iron must now be determined in this precipitate. This may be done by the permanganate, but Wanklyn's colorimetric test is probably better: it is as follows:—Dissolve 1 gramme of pure iron wire in nitro-hydrochloric acid; precipitate the ferric oxide with ammonia; wash the precipitate, dissolve it in a little hydrochloric acid, and dilute to 1 litre: one C.C. therefore equals 1 milligramme of metallic iron; when used it is diluted 1 in 100 so as to make a solution, of which each C.C. contains $\frac{1}{100}$th milligramme (=0·01 of a milligramme) of metallic iron. To use this, dissolve the phosphates of aluminium and iron (obtained by the above described process) in pure hydrochloric acid, and dilute to 100 C.C. Test the solution to see if it give a deep colour with ferrocyanide of potassium: if the colour is not too deep take 50 C.C. of the solution, but if it be deep take a smaller quantity, and make it up to 50 C.C. with distilled water, taking care that it is well acidulated. Put it in a cylindrical glass and add 1 or 2 C.C. of solution of ferrocyanide of potassium: a blue colour is given. In another glass 1 C.C. of strong hydrochloric acid is put, and 50 C.C. of distilled water; 1 or 2 C.C. of ferrocyanide are added; the standard solution of iron is then dropped in till an equal colour is produced. The amount of iron is then read off and calculated as phosphate (1 of iron = 2·696 $FePO_4$). Deduct the weight from the total weight of phosphate of aluminium and iron; the remainder is phosphate of aluminium (= $AlPO_4$), of which 1 part equals 0·42 alumina, or 2·1 dry or 3·9 crystallised potassium alum; or 1·9 dry or 3·7 of crystallised ammonium alum, which last is almost the only kind now in the market.

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[*] In three samples of bread, condemned as inferior, I found 6·2, 6·6, and 8·3 grains of acid (reckoned as crystalline oxalic) per ℔ (=0·89, 0·92, and 1·19 grammes per kilogr. In two samples of good bread, but rather underbaked, 4· and 5·3 respectively (=0·57 and 0·76 per kilogr). For further experiments, see my Report on Hygiene, Army Medical Reports, vol. xviii. (F. de C.).

[†] By Kuhlmann, Letheby, Odling, Wentworth Scott, Crookes, Hassall, Hadow, Horsley, é, Wanklyn.

Wanklyn considers that unalumed bread may contain 5 or 6 milligrammes (=0·005 per cent.) of phosphate of aluminium in every 100 grammes of bread.[*] It will be well to deduct this amount from the total amount of phosphate of aluminium found; the remainder will represent the amount corresponding to alum added.

Dr Letheby has also used a decoction of logwood as a test; a piece of pure bread and a piece of suspected bread are put in a glass containing freshly prepared decoction, and left for twenty-four hours; the pure bread is simply stained, the alumed bread is dark purplish, as the alum acts like a mordant. Mr Hadow has also used this test with advantage, but Mr Crooks, after many experiments, came to the conclusion that it was valueless.[†] Mr Horsley has used it largely, and estimates it highly. His process is as follows—a tincture of logwood is made by digesting for eight hours two drams of freshly-cut logwood in five ounces of methylated spirit. A saturated solution of carbonate of ammonium is also made. A tea-spoonful of each solution is mixed in a wine-glassful of water, in a white ware dish; a slice of bread is put in for five minutes, then removed, and allowed to drain; in an hour or two it turns blue if alum be present.[‡]

Alum is not much used except with inferior bread.[§] The amount of alum in bread is said to be, on an average, 3 ounces to a sack or 280 ℔ of flour; if the sack gives 105 4-℔ loaves, there will be 16 grains in a 4-℔ loaf; if crystallised alum is meant by this, there will only be about 8 grains of dry alum[||] in a 4-℔ loaf. Hassall states the quantity to be ½ ℔ (8 ounces) to 240

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[*] This equals about 5 or 6 grains of crystallised ammonium alum per 4 ℔ loaf.

[†] Chemical News, Sept. 1862.

[‡] Chemical News, May 1872.

[§] Report on Journeymen Bakers, 1862, p.164. See also Odling's Papers. Hassall, however, found alum in half the loaves examined. A writer in the Lancet (Jan. 1872) states that at that date alum was found in 10 out of 20 loaves, and the amount was from 12 to 96 grains in the 4 ℔ loaf.

[||] Mitchell, in his Treatise on the Falsifications of Food, gave a much greater amount; but there is little doubt his alumina was not pure.

℔ of flour, but that the quantity differs for old and new flour. A very good witness,* in the inquiry into the grievances of the journeyman bakers, gave the quantity at 10 ounces per sack; this would give 41·6 grains per 4-℔ loaf. When mixed with flour and baked, the alum is decomposed, part of the alumina combines most strongly with phosphoric acid; and either this or the alum itself is presumed to be in combination with the gluten; bisulphate of potassium is probably formed.

The effects of alum on the flour during the baking have been already noticed. The effects on health will be presently considered.

*Cupric Sulphate.*—Cut a smooth slice of bread, and draw over it a glass rod dipped in potassium ferrocyanide. If copper be present a brick-red colour is given by the formation of ferrocyanide of copper. The test is very delicate. It is believed to be a very rare adulteration in England. It has been said that cobalt is used instead of copper. It is probably a very rare adulteration; it can be detected by the blueness of the ash.†

*Potatoes.*—If potatoes in any quantity have been added, the ash of the bread instead of being neutral is alkaline; this can only occur from sodium carbonate having been added, or from the presence of some salts of organic acid, citrates, lactates, tartrates, which form carbonates on incineration. But if it be from sodium carbonate, the solution of bread will be alkaline, so that it can be known if the alkalinity is produced during incineration. If so, it is almost certain to be from potato.

*Examination of Yeast.*—Common brewers' yeast is not likely to be adulterated. If any solid mineral substances are mixed with German yeast, they are detected either by washing or by incineration. Dr Letheby found German yeast, imported in 1863, to be adulterated with 30 per cent. of pipe-clay.

### *Microscopical Examination of Bread.*

Under the microscope some starch-cells can be seen, but they are generally enlarged and partly broken up; often they are broken up altogether, and form little angular masses which might be mistaken for rice starch-grains. The gluten forms little stringy masses. Sometimes with a low power some dark points are seen; under a high power, 500 or 600 diameters, these are found to be formed of a number of dark little rods joined together. This is a kind of bacterium often found in large quantities in yeast, and is carried into the bread. It must not be mistaken for an impurity.

*Fungi.*—The most common fungus is a kind of *Penicillium* (*sitophilum* and *roseum*), greenish, brownish, or reddish yellow colour; sporules, sporangia, and mycelium can all be seen. The *Oidium aurantiacum* has been several times detected in France and Algeria; it is distinguished by its orange-red colour. A greenish mucor is often found in bread. I have not yet seen the Puccinia so common in flour.

### *Microscopical Examination for Adulterations.*

Rice flour cannot be detected unless it is in very large quantity; then the number of small angular grains may create suspicion, often unfortunately nothing more than suspicion. Potato starch is often completely broken up and cannot be detected; potato itself is used, little masses of it can often be found, and some starch-grains with eccentric hilum. Incineration for the alkaline ash is useful in this case.

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* Report on the Journeymen Bakers, 1862, p. 163. Some of the statements are beyond even this amount—1 to 4 ℔ per 1000 (4-℔ ?) loaves (p. xxxvi.); but this is probably an exaggeration.

† I have to thank my friend Dr Campbell Brown for this information.

Bean and pea flour, if more than 4 per cent., give a dark colour to the bread, the starch cells can often be found; moistening the bread with hot water sometimes produces the peculiar smell of the pea.

The microscopical examination of bread for adulteration is unsatisfactory; the flour should be examined instead, whenever it can be obtained.

### *Diseases connected with the Quality of Flour and Bread.*

1. *The Flour originally bad.*—It may be ergoted, or grown and fermenting, or with fungi forming. An anomalous disease approaching to ergotism should lead at once to an examination of the flour. The fermenting flour produces dyspepsia and diarrhœa; the heat and moisture of the stomach, no doubt, excite at once very rapid fermentation; the gluten, already metamorphosing, acts very energetically on the starch, and carbonic acid is rapidly developed; hence uncomfortable feelings, flatulence, imperfect digestion, and diarrhœa. It is to remedy this condition of flour that alum is added, and some of the effects ascribed to alum may be really owing to the flour.

The most important disease connected with flour is, however, ergotism; this is less common in wheat than in rye flour, but yet is occasionally seen. Sometimes ergoted meal produces at once violent stomach and intestinal symptoms, at other times primary digestion is well performed, and the early symptoms are great general depression and feverishness, ushering in the local symptoms of acrodynia.

2. *Flour originally good, but altering either from age or from not having been well dried.*—The bread is often acid, and sometimes highly so; this may produce diarrhœa, though I have known such bread used for a long time without this effect; usually persons will not eat much of it, and thus the supply of nutriment is lessened. If the bread be too moist, fungi form, and the *Oidium aurantiacum*, in particular, has been known in Algiers to give rise to little endemics of diarrhœa (Boudin and Foster).* The *Mucor mucedo* either does not produce this, or rarely. It should be remembered, however, that mouldy oats (the fungus being the Aspergillus) have given rise to paralytic symptoms in horses, so that these fungi are to be looked on with suspicion; † and a new case of the kind has lately been reported by H. Hoffman in Giessen (Virchow's "Archiv," band xliii. p. 173). Professor Varnell also states ‡ that six horses died in three days from eating mouldy oats; there was a large amount of matted mycelium, and this, when given to other horses for experiment, killed them in thirty-six hours; there was a "peculiar growth" on the mucous membrane of the small intestine. It is not known that the Acarus so common in flour has any bad effects when eaten.

3. *Substances added.*—Alum, of course, is the chief substance; there has been much difference of opinion as to its effects. It has been asserted to produce dyspepsia; to lessen the nutritive value of bread by rendering the phosphoric acid insoluble, and to be also a falsification, inasmuch as it permits an inferior flour to be sold for a good one. The last allegation is no doubt correct; the second probably so, as there is little doubt of the formation, and none of the insolubility, of phosphate of alumina. The first point is more doubtful, though several physicians of great authority (Carpenter, Dundas Thomson, Gibbon, Normandy) have considered its action very deleterious, and that it causes dyspepsia and constipation. Pereira considered that whatever may have been the effect in the case of healthy persons, sick persons did really

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* Archives Gen. de Méd., 1848, p. 244.

† Sanderson's Report in Syd. Soc. Year-Book for 1862, p. 462.

‡ Journal of the Society of Arts, April 1865.

suffer in that way. A question like this is obviously difficult of that strict proof we now demand in medicine, and personally I have been able to come to no conclusion. Seeing, indeed, that the usual effect of bad flour is flatulence and diarrhœa, if constipation were decidedly produced by bread, it would be more likely to proceed from alum than from any other ingredient of the bread. Looking again to the fact that sometimes bread has contained large quantities of alum,—sometimes as much as 40 grains in a 4-℔ loaf, and probably more,—we get an amount in an ordinary meal which (if the aluminium phosphate is an astringent) might very well cause constipation. Looking, then, to the positive evidence, and the reasonableness of that evidence, it seems to me extremely likely that strongly alumed bread does produce the injurious effects ascribed to it.

The addition of alum is forbidden by law.

Sulphuric acid is said to be added* before grinding instead of alum; it has the same power of preventing decay.

As already stated, lime water may be used, and with advantage.

*Sulphate of Copper.*—The amount used is so small that it seldom produces any symptoms; still it is possible that some anomalous cases of stomach irritation might be owing to this.

*Lead.*—Dr Alford,† medical officer for Taunton, reports a case of poisoning from lead getting into flour. Six or seven families, including 15 to 20 persons, suffered, some very severely. The water was analysed but no lead found, and then it was noted that the persons attacked all got their flour from the same mill. On making inquiries it was found that the millstones used had (from the nature of the stone) large spaces in them, which had been filled up with lead! It was mentioned at the meeting of the sanitary authority, by one of the members, that lead was not usually employed in that way, that what was generally used was *red-lead* and borax, or alum and borax, both highly objectionable. If such be the case this is another possible source of alum, which ought to be recollected.

The *Lolium temulentum* gives rise to narcotic symptoms (see *ante*).

*Flour from other Grains.*—It is not known whether the addition of potatoes, rice, barley, peas, &c., in any way injures health, except as it may affect nutrition or digestion. Occasionally, in times of famine, other substances are mixed—chestnuts, acorns, &c. In 1835, during famine, fatal dysentery appeared in Königsberg, owing to the people mixing their flour with the pollen of the male catkin of the hazel bush. In India the use of a vetch, *Lathyrus sativus* (kessaree-dholl), with barley or wheat, gives rise to a special paralysis of the legs, when it exceeds one-twelfth part of the flour (Irvine in "Indian Annals"); the *L. cicera* has the same effect.‡ During the siege of Paris, straw, to the extent of one-eighth, was introduced into the bread: this had a very irritating effect.

## SECTION III.

## BARLEY.

As an article of diet barley has the same advantages and disadvantages as wheat. It is said to be rather laxative (Pereira), and I have myself noticed that either from this cause, or from the imperfect separation of the sharp husks, barley bread is particularly unsuited for dysenteric cases. It contains rather more protein bodies than wheat, and these consist of gluten-casein, gluten-fibrin, mucedin, and albumen.* It is certainly very nutritious, and the Greeks trained their athletes on it. Its richness in phosphoric acid and iron render it particularly adapted for this.

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* Dr Angus Smith, Annual Report of the Manchester and Salford Sanitary Association for 1863.—Report of Sub Committee.

† Sanitary Record, May 25th, 1877.

‡ Dr Irvine has lately ("Indian Annals," Jan. 1868) again described the symptoms produced by the kassaree-dholl or Lathyrus. The first symptoms are gastro-intestinal irritation, and the paraplegia follows on this.

*Choice of Barley.*—(Scotch or pot barley, viz., the grain without the husks.) For the barley grains the same points are to be attended to as in wheat.

For the pearl barley (which is merely the grain rounded off), the best tests are the physical characters, colour, freedom from dust, grit, and insects, and the test of cooking.

The patent prepared or powdered barley should be examined with the microscope ; any kind of cheaper grain may be mixed with it. (See figures of barley and other grains.)

*Diseases arising from Altered Quality.*—These are the same as those of wheat—viz., indigestion, flatulence, and diarrhœa. I am not aware that there is anything peculiar in the action of diseased barley as distinguished from wheat.

## SECTION IV.

## OATS.

Oats have been considered even more nutritious than wheat or barley, and, certainly, not only is the amount of nitrogenous substance great, but the proportion of fat is large. Unfortunately, the nitrogenous substance has no adhesive property, and bread cannot be made ; the amount of indigestible cellulose is large. But, on the other hand, oatmeal has the great advantage of being very readily cooked, much more so than wheat or barley. The late researches of Kreusler (Ritthausen, *op. cit.* p. 125) show that the nitrogenous substances of oats contain gliadin, and especially gluten-casein. This last substance is that called " avenin " by Norton and Johnstone ; it approaches very closely to the legumin of peas and beans, and is so called by Ritthausen. In nutritive properties it causes oatmeal to stand nearer to the Leguminosæ than the cereals do. It contains double as much sulphur as the legumin of peas.

For this reason, and because it contains much nutriment in small bulk, because it can be eaten for long periods with relish, and keeps unchanged for a long time, it would seem to be an excellent food for soldiers during war—an opinion which does not lose in force, when we remember that it formed the staple food of one of the most martial races on record, the Scotch Highlanders, whom Jackson considered also one of the most enduring. Formerly, when oats were badly cleaned, intestinal concretions of the husk and hairs were common among those who lived on oatmeal, but these are now uncommon. It has been thought to be " heating " when taken continually, but this is probably a prejudice. The supporting qualities of oatmeal used as a drink, made into a thin gruel, are testified to in hard work by the chief and divisional engineers of the Great Western Railway.†

*Adulterations.*—Barley-meal and the husks of barley, of wheat, and of oat itself, are added very frequently. A single look through the microscope detects the round and smooth barley starch ; the envelopes are recognised with very little more trouble. Rice and maize are also sometimes used.

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* Ritthausen, *op. cit.* p. 103.

† On the issue of a spirit ration during the Ashantee Campaign of 1874, Appendix ii., by E. A. Parkes, M.D., F.R.S., &c., 1874.

The drawings already given will also enable these substances to be detected. Hassall found about half the samples of oatmeal adulterated.

*Choice of Oatmeal.*—There should be a good proportion of envelope, but no branny character, which usually arises from barley husks; the starch should not be discoloured. A microscopic examination should always be made, both for adulterations and Acari.

## SECTION V.

## MAIZE AND RYE.

Both these grains are very nutritious; maize contains a large quantity of yellowish fat (6 to 7 per cent.) The gluten cannot be washed out as in wheat, though this was stated by Gorham, who found a special substance which he termed "Zeïn." This is called "maize-fibrin" by Ritthausen. It requires very careful cooking, as otherwise much passes out undigested. My friend, Dr Johnston, has communicated to me the particulars of an outbreak of diarrhœa in a military prison clearly due to badly cooked maize. It should be soaked in water, but not too long (two to four hours), and then thoroughly boiled for several hours (four to six) at a rather low heat. Maize cakes are both palatable and nutritious.

Rye makes a very acid dark bread, which causes diarrhœa in those unaccustomed to it; custom, however, soon remedies this, and, as far as nutritive value goes, it appears equal to wheat. It contains less vegetable fibrine, and more casein and albumen, and a peculiar odorous substance.

### *Diseases connected with Maize and Rye.*

It is presumed that alterations in the flour will produce the same diseases as in the analogous case of wheat. Ergotism is, however, more common in rye than any other grain. The Pellagra of Lombardy has been ascribed to a fungus (Verderame, or Verdet) forming in the maize. Many volumes, with different statements, have been written on this point, and it is still doubtful whether or not the Verdet has this effect. The evidence is not sufficient, but, on the whole, seems to me most in favour of the view which connects Pellagra with diseased maize.

## SECTION VI.

## RICE.

The whole grain (paddy) deprived of the husk is sold as rice. There are many varieties, of different colours (white, red, brown?) and composition. The amount of nitrogenous matter varies greatly, from 3 to 7·5 per cent. of the moist grain. As an article of diet, it has the advantage of an extremely digestible starch-grain, and, like the other Cerealia, there is a great admixture of substances; it is, however, poorer in nitrogenous substances than wheat, and is much poorer in fat. Consequently, among rice-feeding nations, leguminous seeds are taken to supply the first, and animal or vegetable fats to remedy the latter defect. Rice is also poor in salts.

*Cooking of Rice.*—It should properly be steamed, not boiled, and the steaming should be thoroughly done, else the starch-grains are not swollen and digestible. If boiled, it should be for a long time at a low temperature; the rice (or conjee) water contains some albuminous matter, and the grain loses in nutritive power.

*Choice of Rice.*—The grains should be clean, without grit; the individual grains without spots or evidence of insects. The size varies much, according to the kind; the large kinds usually command the highest market price.*

*Comparison of the foregoing Grains—Order of Richness.*

| Nitrogenous Substances. | Fat. | Starch, &c. | Salts. |
|---|---|---|---|
| Wheat. | Maize. | Rice. | Barley. |
| Barley. | Oats. | Maize. | Oats. |
| Rye. | Barley. | Wheat. | Wheat. |
| Oats. | Rye. | Rye. | Rye. |
| Maize. | Wheat. | Oats. | Maize. |
| Rice. | Rice. | Barley. | Rice. |

## SECTION VII.

## MILLET, RAGGY, BUCKWHEAT, GRAM.

Various other grains belonging to the Cerealia, or to other natural orders, but having similar properties, are used as food in different countries. Of these, the above named are chiefly those the medical officer may have to report on.

Millet is used largely in Africa (west coast) and Algeria, in Italy, Spain, Portugal, some parts of India, China, &c.

| English Names. | Botanical Names. | Indian Names. |
|---|---|---|
| Common millet, | Panicum miliaceum, | Sawee Chennawaree (Hindustani).<br>Varagoo (Tamul). |
| Small millet, | Sorghum or Panicum vulgare, | Dhurra (Arabic).<br>Cholam (Tamul).<br>Joar or Jowree (Hind.). |
| Spiked millet, | Penicillaria spicata, | Bájra or Bajree (Hind.).<br>Cumboo (Tamul). |
| Golden-coloured millet, | Sorghum saccharatum, | |
| Italian millet, | Setaria Italica, | Kala kangnī (Hind.).<br>Tenay (Tamul). |
| German millet, | Setaria Germanica, | |
| | Eleusine corocana, | Raggee or Raggy (Hind., Canarese, and Tamul).<br>Murha and Maud in the N. Prov. of Hindustan. |

The table sufficiently expresses the composition of most of these.†

*In 100 parts of Meal (freed from Bran).*

| | *Panicum miliaceum* (Common Millet). | *Penicillaria spicata*; a kind of Millet much used in India under the name of Bajra. | *Sorghum vulgare*, Dhurra of the Arabs, Joar or Jowaree of India. |
|---|---|---|---|
| Water, . . . . . . | 12·22 | 11·8 | 11·95 |
| Nitrogenous substances, . | 9·27 | 10·13 | 8·64 |
| Dextrin, . . . . . | 9·13 | ... | 3·82 |
| Sugar, . . . . . . | 1·80 | ... | 1·46 |
| Fat, . . . . . . . | 7·43 | 4·62 | 3·9 |
| Starch, . . . . . | 59·04 | 71·75 | 70·23 with husks. |
| Silica, . . . . . . | 0·11 | ... | ... |

---

* The larger grains—especially the American kinds—have often much less flavour than the smaller and less attractive Indian kinds.

† The native names of the Indian grains and pulses used, especially in Southern India, are

The ash is about 3 per cent. in Panicum, 2·6 in Penicillaria, and 1·7 in Sorghum. When freed from silica, which is present in large amount, the ash contains 20 per cent. of potash, 24 of magnesia, a little soda, no lime, and about 50 per cent. of phosphoric acid.

The other millets ((*Setaria germanica* and *Panicum sanguinale*) are very similar in constitution.

Millet bread is very good, and some was issued to the troops in the last China Expedition. This should always be done in a millet country, if wheat or barley cannot be got. In Northern China millet is almost exclusively used.

Raggy or Ragee, Murha and Maud of the upper provinces (*Eleusine corocana*), a millet, is largely used in Southern India (Mysore), and in some parts of Northern Hindustan, and is considered even more nutritive than wheat.* It is very indestructible, and can be preserved for many years (even sixty) in dry grain pits.

Buckwheat † and Gram are not so likely to be used. The former is poor in nitrogenous substances and fat, but makes a fair tasting bread.

Gram bread or cakes have been occasionally used in India for Europeans, and this use might be extended; the cakes are palatable, and extremely nutritious, as may be seen by the tables (see note, page 253).

## SECTION VIII.

### LEGUMINOSÆ.‡

The Leguminosæ, in respect of dietetic properties, are broadly distinguished

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given very fully in a paper by Mr Elliot (Edinburgh Philosophical Journal, July 1862); and also in Mr Cornish's excellent paper (Madras Medical Journal, February 1864).

* For the Indian grains and pulses, Dr Forbes Watson's admirable paper can be consulted, also the papers by Mr Elliot and Dr Cornish already referred to.

† *Polygonum Fagopyrum*, or *Fagopyrum esculentum* (Buckwheat), used in some parts of Russia, Germany, and France.

In 100 parts.

| | | | |
|---|---|---|---|
| Water, . . . . | 12·754 | Sugar, . . . . . | 0·914 |
| Nitrogenous substances, | 2·645 | Fat, . . . . . | 0·943 |
| Dextrin, . . . . | 2·850 | Starch, . . . . | 79·894 |

The ash is about 1·09 per cent., and contains chiefly potash, magnesia, and phosphoric acid. Other species of buckwheat are *P. tataricum* and *P. emarginatum*.

‡ Composition of Dried Grain :—

| | *Pisum sativum*—Peas. | *Phaseolus vulgaris*—Kidney Bean. | *Vicia Faba*—Common or Broad Bean. |
|---|---|---|---|
| Water, . . . . . . | 14·5 | 16 | 12·8 |
| Legumin, albumen, and gluten-like substances, . . . | 22·3 | 22·5 | 22 |
| Cellulose, . . . . . | 4·9 | 4·4 | 5 |
| Starch and Dextrin and Sugar, . | 52·6 | 49·9 | 52·6 |
| Fat, . . . . . . | 2 | 2 | 1·6 |
| Chlorophyll, . . . . . | 1·2 | ... | ... |
| Salts, . . . . . . | 2·4 | 2·4 | 2·5 |
| Potash, . . . . . . | ·86 | ·98 | ·62 |
| Soda, . . . . . . | ·16 | ·24 | ·34 |
| Lime, . . . . . . | ·1 | ·23 | ·15 |
| Magnesia, . . . . . | ·18 | ·18 | ·2 |
| Iron, . . . . . . | ·023 | ·001 | ·03 |
| Phosphoric acid, . . . . | ·85 | ·64 | ·9 |
| Sulphuric acid, . . . . | ·077 | ·07 | ·08 |
| Chloride of potassium, . . . | ·067 | ... | ... |
| Chloride of sodium, . . . . | ·044 | ... | .. |
| Chlorine, . . . . . . | ... | ·025 | ·06 |

from other vegetables by their very large amount of nitrogenous substance, called legumin or vegetable casein; there are in addition, a little albumen and other protein bodies. The advantages of peas and beans as articles of diet are the great amount of this substance, and the existence of much sulphur and phosphorus in combination with the legumin; in salts also they are a little richer than the Cerealia, especially in potash and lime, but are rather poorer in phosphoric acid and magnesia; 1 ℔ of peas contains about 168 grains of salts. The disadvantage of peas and beans are a certain amount of indigestibility; about 6·5 per cent. of the ingested pea passes out unchanged, and starch-cells, giving a blue reaction with iodine, are found in the fæces; much flatus is also produced by the sulphuretted hydrogen formed from the legumin. Still, they are a most valuable article of food, and always ought to be used when much exercise is taken, as they are an excellent addition to meat and Cerealia. Both men and beasts can be nourished on them alone for some time. Added to rice, they form the staple food of large populations in India.* Mr Cornish mentions that, in the Sepoy corps, the men are much subject to diarrhœa from the too great use of the "dholl" (*Cajanus indicus*).

*Choice of Pea.*—By keeping, peas lose their colour, become very pale and much shrivelled, and extremely hard. Anything like decomposition, or existence of insects, is at once detected. The powder does not keep very long; the whole peas should be split.

The microscope should be used to detect the Acarus. The characters of the *Pea* and *Bean Starch* have been already given.

*Cooking of Peas and Beans.*—They must be boiled slowly, and for a long time, otherwise they are very indigestible. If old, no amount of boiling softens them; in fact, the longer they are boiled the harder they become; they should then be soaked in cold water for twenty-four hours, crushed, and stewed; in this way even very old peas may be made digestible and palatable. Chalk-water must be avoided in the case of peas as of other vegetables, as the lime-salts form insoluble compounds with the legumin.

*Lathyrus sativus* (Kassaree-dholl of India).—Occasionally in Europe, and constantly in some parts of India, this vetch has been used when mixed with wheat or barley flour for bread. When used in too great quantities, it produces (without there being necessarily any alteration of the grain?) constipation, colic, and some form of indigestion, and if eaten in large quantity, paraplegia. It is also injurious to horses, but less so to oxen. In Bengal,

Chief Indian Peas and Beans (after Forbes Watson), in 100 parts (without husks):—

| | *Pisum sativum*—Analysis of Indian Pea, Bombay and Bengal (Buttamee, Hindustani). | *Cajanus indicus*—A Pea called Dholl or Toor-dholl in India. | *Phaseolus*—Ooreed of India. | *Soja hispida*—(A Bean) Bhoot of India. | *Dolichos*—(A Bean) Wall or Ghot-wall or Cooltee of India. | *Ervum Lens*—Lentil, called Dholl, like the Cajanus, or Mussoor in Hindustani.† | *Cicer arietinum*—Gram or Gramdhall. |
|---|---|---|---|---|---|---|---|
| Water, . . | 11·79 | 10·63 | 12·44 | 10·25 | 12·03 | 11·84 | 11·39 |
| Nitrogenous substances, . . | 27·96 | 22·18 | 24·73 | 38·83 | 23·27 | 25·15 | 22·70 |
| Fat, . . . | 1·47 | 1·95‡ | 1·36 | 10·51 | 2·20 | 1·26 | 3·76 |
| Starch, . . | 56·36 | 62·13 | 58·76 | 26·65 | 59·38 | 59·85 | 63·18 |
| Mineral Matters, | 2·48 | 3·11 | 3·17 | 4·14 | 3·19 | 1·92 | 2·60 |

† Not liked by the Hindus, on account of its red blood-like colour.

‡ A little oil is often mixed with Dholl, which increases the fatty matter to 3 or 4 per cent.

Dr Irving* found in some villages no less than from 10 to 15 per cent. of the people paralytic from this cause.

From its composition, it would not appear to be innutritious. Without husks, it is composed of—

| | | | |
|---|---|---|---|
| Nitrogenous substances, | 27·96 | Ash, . . . | 2·48 |
| Fat, . . . . | 1·47 | Water, . . . | 11·72 |
| Starches, . . . | 56·30 | | |

## SECTION IX.

## STARCHES† AND SUGAR.

### SUB-SECTION I.—ARROWROOTS.

*Maranta Arrowroot* (West Indian).—The chief kind is obtained from the *Maranta arundinacea.* The quality of Maranta arrowroot is judged of by whiteness; by the grains being aggregated into little lumps, and by the jelly being readily made, and being firm, colourless, transparent, and good tasted. The jelly remains firm for three or four days without turning thin or sour, whereas potato flour jelly in twelve hours becomes thin and acescent. Under the microscope the starch-grains are easily identified. They are slightly ovoid, like potato starch, but have a mark or line at the larger end (the hilum of the potato starch is at the smaller end), the concentric lines are well marked. The most common adulterations are sago, tapioca, and potato starch. All these starch-grains are readily detected by the microscope.

*Curcuma Arrowroot.*—Arrowroot obtained from the Curcuma has the same physical characters as Maranta, but under the microscope the starch-grains are large and oblong, marked with very distinct concentric lines, which, however, are not entire circles, having an indistinct hilum at the smaller end.

*Manihot Arrowroot.*—This is obtained from Rio. The starch-grains are very marked. (See Plate of Starches.)

*Tacca or Otaheiti Arrowroot.*—I have never seen this arrowroot, but Hassall gives a figure which shows that the starch-grains resemble those of the Manihot.

*Arum Arrowroot.*—The Arum or Portland arrowroot has small, angular, and facetted starch-grains, which cannot be confounded with any of the former. They are a little like maize. This is sometimes called Portland Sago.

*British or Potato Arrowroot.*—Under the term "Farina," potato starch is sold in the market; so white and crackling, and making so good a jelly, that it is not always easy to distinguish it from Manihot. The microscope at once detects it (see page 232). The pear-shaped grains, marked hilum towards the smaller end, and the swelling with weak liquor potassæ, render a mistake impossible. In making the jelly a much larger quantity is required than of the Maranta arrowroot.

*Canna or* Tous les Mois *Arrowroot.*—The starch-grains are like those of the potato, but much larger, and the concentric lines are beautifully marked and distinct. (See Plate of Starches.)

### SUB-SECTION II.—TAPIOCA.

This is obtained from the finest part of the pith of *Jatropha manihot* or *Cassava.*

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* Indian Annals, 1857. Ibid., Jan. 1868, p. 89, Dr Irvine notices the resemblance of the symptoms to the Barbiers of Bontius.

† See table p. 255; and plate of drawings by Dr. Maddox farther on.

Under the microscope the starch-grains are small, with a central hilum; and sometimes three or four adhere together and form compound grains.

It is adulterated with sago and potato starch, both of which are easily detected by the microscope. (See Plate of Starches.)

### SUB-SECTION III.—SAGO.

The best kinds are derived from the sago palm (*Sagus farinifera*), but the sago of the *Cycas circinalis* is also sold; it is, however, inferior.

Granulated sago is either "common" or "pearl;" the latter is chiefly used in hospitals. The starch is soluble in cold as well as in hot water. The starch-grains are elongated, rounded at the larger end, and compressed at the other; and hence their shape is quite different from the potato starch. The hilum is a point, or more often a cross, slit, or star, and is seated at the smaller end; whereas, as in the Maranta arrowroot, the hilum is at the larger end. Rings are more or less clearly seen.

In the market is a factitious sago made of potato flour. This is sometimes coloured red or brownish, either from cochineal or sugar. In thirty specimens Hassall found five to be fictitious. The microscope easily detects potato starch.

It is sometimes difficult to remember the characters of the different forms of starch, but it may be to a certain extent facilitated by a tabulated arrangement. The following table has been compiled by Dr J. D. Macdonald, R.N., F.R.S.

*Microscopical discrimination of the principal Arrowroots and Starches.*

I. *Starches* with isolated smooth or unfacetted grains, being originally free in the cell cavity.

| General Characters. | | Particular Characters. | | Name. |
|---|---|---|---|---|
| *Form.* | *Hilum.* | *Form.* | *Hilum.* | |
| A.—Contour ovoid. Hilum eccentric. | Hilum at the small end, grains large. | Outline even. Continuous rings, including more than half the grain. | Hilum distinct. | Potato; British arrowroot. |
| | | Outline even. Continuous rings, including less than half the grain. | Hilum distinct. | Tous - les - mois (Canna) arrowroot. |
| | | | Hilum indistinct. | Curcuma arrowroot. |
| | Hilum at the larger end, grains medium sized. | Outline uneven, often with beak-like projections. | Hilum slit-like, triradial or crucial. | Bermuda (Maranta) arrowroot. |
| | | Outline more even, beak less frequently seen. | Hilum similar, but less apparent. | St Vincent arrowroot. |
| | | Whole grain still smoother and more regular. | Hilum similar, but still less marked. | Natal arrowroot. |
| B.—Contour oval. | Hilum longitudinal, linear lateral. | Grains often broad and reniform. | Hilum cleft-like, puckered, irregular. | Bean starch. |
| | | Grains narrower and more uniform. | Hilum less puckered and more regular. | Pea starch. |
| C.—Contour round. | Hilum central. | Form lenticular. | Surface convex at the hilum. | Wheat starch. |
| | | | Surface depressed at the hilum. | Barley starch. |
| | | Form spherical. | Hilum often deeply fissured, star-like. | Rye starch. |

II. *Starches* with the grains facetted by original juxtaposition in the cell cavity. Hilum central.

| | | | | |
|---|---|---|---|---|
| —Often presenting the rounded free surface of grains originally superficial in the cluster. | Hilum often cavernous. | Grains very large. (Rings sinuous, irregular.) | | Sago. |
| | | Small. (Sago in miniature.) | | Tapioca. |
| | Hilum stellate. | Small. (Like Tapioca without preparation.) | | Rio arrowroot. |
| 3.—Altogether facetted. | Hilum stellate. | Small. (Discoidal with facetted margin.) | | Maize. |
| | Hilum inconspicuous. | Very small. | In rounded glomeruli or compound grains, and free. | Oats. |
| | | | Closely packed in the cells, and fixed. | Rice. |

## SUB-SECTION IV.—SUGAR.

*Choice and Examination.*—The sugar should be more or less white, crystalline, not evidently moist to the touch, and should dissolve entirely in water, or leave merely small fragments, which on examination with the microscope will be found to be bits of cane. The whiter the quality the less is the percentage of water, which varies in different kinds of sugar, from about ·25 per cent. (in the finest sugars) to 9 or even 10 per cent. (in the coarse brown sugars).

The unpurified sugars contain albuminous matters which decompose, and a sort of fermentation occurs. The Acarus, or sugar-mite, is usually found in such sugar, which is not known to be hurtful. Fungi also are very frequently present.

### *Method of Examination.*

1. Determine physical characters of colour, amount of crystallisation, &c.
2. Dissolve in cold water; fragments of cane, starch, sand, gypsum, phosphate of lime are left behind; test with iodine for starch. The best way is to dissolve under the microscope, as all adulterations are then at once detected.
3. Determine percentage of water by drying thoroughly 10 grammes, and again weighing.
4. Excess of glucose (a little is always present) is detected by the large immediate action on the copper solution.

## SECTION X.

## SUCCULENT VEGETABLES.

Almost all other vegetables are used, not so much on account of nutritive qualities, as for the supply of salts; some of them, however, contain very digestible starch and sugar, or other substances, such as pectin or asparagin, or peculiar oils which act as condiments, as in onions.

### SUB-SECTION I.—POTATOES (SOLANUM TUBEROSUM).

The composition has been already given (p. 195). The salts are noted below.* It will be observed from these, and from the tables already given, that the amount of potash and phosphoric acid is not so great as in some other substances; the true use of the potato is probably to be found in the large amount of salts (malates? tartrates? citrates) which form carbonates on incineration. The juice of the potato is acid. There is no better antiscorbutic than the potato, and its starch its very digestible. The citric acid is combined with potash, soda, and lime.

As the amount of salts is small, and that of water large, at least 8 to 12 ounces of potatoes should be taken daily if no other vegetables are eaten (= 8 ounces at 1 per cent. of salts contain 35 grains; at 1·5 per cent. = 52·5 grains).

*Choice.*—Potatoes should be of good size, firm, cut with some resistance, and present no evidence of disease or fungi.

A still better judgment may be formed by taking the specific gravity, and using the following tables:—

*Potatoes.*—The solids can be determined by taking the specific gravity, and multiplying it by a factor taken from the table below, and dividing by 1000; the result is the percentage of solids:—

| Specific gravity, between | Factor. | Specific gravity, between | Factor. |
|---|---|---|---|
| 1061—1068 | 16 | 1105—1109 | 24 |
| 1069—1074 | 18 | 1110—1114 | 26 |
| 1075—1082 | 20 | 1115—1119 | 27 |
| 1083—1104 | 22 | 1120—1129 | 28 |

If the starch alone is to be determined, deduct 7 from the factor, and proceed as above, the result is the percentage of starch.

If the specific gravity of the potato is—

| | | |
|---|---|---|
| Below | 1068 | The quality is very bad. |
| Between | 1068—1082 | ,, inferior. |
| Between | 1082—1105 | ,, rather poor. |
| Above | 1105 | ,, good. |
| Above | 1110 | ,, best. |

As, however, the medical officer will seldom have an hydrometer† which will give so high a specific gravity, and must work, therefore, with a common urinometer, the following plan must be adopted:—Take a sufficient quantity of water, and dissolve in it ½ an ounce or an ounce of salt, and take the specific gravity; then add another ½ ounce or ounce, and take again the specific gravity; do this two or three times, so as to get the increase of specific gravity for each addition of a known quantity of salt; then add salt enough to bring up the specific gravity to the desired amount. This is, of course, not

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* *Potato.*—Percentage amount of ash 1· to 1·5. Mineral constituents in 100 of ash.

| | (Way.) | (Fromberg.) | | (Way.) | (Fromberg.) |
|---|---|---|---|---|---|
| Potash, . . . . | 46·60 | 50·23 | Chloride of sodium, | 3·43 | ... |
| Soda, . . | ... | 3·7 | Carbonic acid (from the incineration of organic acids), | 13·30 | ... |
| Magnesia, . . | 8·70 | 4·4 | Oxide of iron, | ? | ... |
| Lime, . . . . | 4·54 | 0·83 | Silicate of alumina, | 1·95 | ... |
| Phosphoric acid, . | 13·30 | 10·10 | | | |
| Sulphuric ,, . | 4·66 | 14·67 | | | |
| Chloride of potassium, | ... | 11·76 | | | |

The carbonate of potassium is produced in the incineration from the vegetable salts (citrate, malate, tartrate of potassium). An analysis of Vogel's gives no less than 21 per cent. of carbonate of potassium and 34 per cent. of carbonate of sodium in 100 of ash.

† Baumé's or Twaddell's hydrometers are the best for the purpose.

quite accurate, but in the absence of proper instruments it is the only plan I can devise.

*Cooking of Potatoes.*—The skins should not be taken off, or a large amount of salts passes into the water; using salt water is a good plan, as fewer of the salts then pass out. The boiling must be complete, as the starch-grains are otherwise undigested, and it must be slow, else the cellulose and albuminates are hard. Steaming potatoes is by far the best plan; the heat must be moderate; the steam penetrates everywhere, and there is no loss of salts.

*Preservation of Potatoes.*—Sugar, in the form of molasses, is the best plan on a large scale; a cask is filled with alternate strata of molasses and peeled and sliced potatoes. On a small scale, boiling the potatoes for a few minutes will keep them for some time. Free exposure to air, turning the potatoes over and at once removing those that are bad, are useful plans.*

The preserved potatoes are sliced, dried, and granulated, and when well prepared, are extremely useful.

The Sweet Potato and the Yam are somewhat similar to the ordinary potato; see below in foot-note.†

### SUB-SECTION II.—OTHER VEGETABLES.

The composition of Carrots and of Cabbage has been already given (p. 195). Two or three of the common kinds of vegetables may be added—

| | Water. | Albumen and Casein. | Starch, Sugar, and Dextrin. | Fat. | Woody Fibre. | Mineral Substances. |
|---|---|---|---|---|---|---|
| Turnip (*Brassica rapa*), . . | 90·50 | 1·100 | 4·000 | ... | 2·400 | 0·500 |
| Parsnip (*Pastinaca sativa*), . . | 82·04 | 1·215 | 6·389 | 0·546 | 8·022 | 1·041 |
| Jerusalem artichoke (*Helianthus tuberosus*), . . | 76·35 | 0·900 | 19·000 | 0·900 | 1·220 | 1·610 |

Other vegetables contain special ingredients, such as asparagin in asparagus (a small amount is also contained in potatoes), wax, pectin, which is a little more oxidised than starch or sugar; or peculiar oils and savoury or odoriferous matters.

On account of its volatile oils, the onion tribe is largely used, and is a capital condiment, and has an effect as an anti-scorbutic.

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* In the Crimean war there was a considerable loss of potatoes sent up to Balaklava, and at a time when the men were most in need of them. The addition of sugar to the raw potatoes might have been made.

† SWEET POTATO (CONVOLVULUS BATATA).

Composition per cent.—

| | | | |
|---|---|---|---|
| Water, . . | 67·5 to 73 | Albumen, . . . . | 1·5 |
| Starch, . . | 13 to 16 | Fat, . . . . | ·3 |
| Sugar, . . | 6 to 10 | Salts, . . . . | 2·9 |
| Pectic acid, . . | 1·2 | Cellulose, . . . | 2·5 |

This vegetable is very rich in sugar and in salts. It may be usefully employed for soldiers, wherever it can be procured, in lieu of potatoes, for some time.

YAM (DIOSCOREA SATIVA).

Composition—

| | | | |
|---|---|---|---|
| Water, . . . . . | 74 | Pectin, . . . . . | 2·8 |
| Albuminates, . . . . | 2 | Cellulose, . . . . | 2·2 |
| Starch, . . . . . | 16 | Fat, . . . . . | ·5 |
| Sugar, . . . . . | ·2 | Salts, . . . . . | 1·3 |

This also is a useful vegetable, though inferior to the potato and batata. It is largely used for soldiers in the West and East Indies.

Onion contains some citrate of lime.

There are many vegetables which can be employed as anti-scorbutics besides potatoes, onions, and green vegetables. The wild artichoke and the *Agave americana* (cactus) are both excellent anti-scorbutics, and the latter is said to be better than lime juice. Sorrel, and in a less degree scurvy-grass and mustard and cress, are useful. In New Mexico a salad made of the "lamb's quarter" (*Chenopodium album*) has been found very useful.[*]

In war almost any kind of vegetables may be used rather than that the troops should be left without such food. In one of the Caffre wars, an African corps kept free from scurvy by using a sort of grass (?) in their soup.

The dried vegetables, and especially the dried potato, have considerable anti-scorbutic powers (Armstrong).[†] The dandelion was largely used in the French army in the Crimean war. The American Indians put up for winter quantities of dried plums, buffalo berries, and choke berries, and thus escape scurvy ("Hamilton's Mil. Surg." p. 212).

If vegetables cannot be procured, citrate, tartrate, and lactate of potassium should be given.

## SECTION XI.

## COW'S MILK.

A cow gives very variable quantities of milk, according to food and race, and age of the calf; perhaps 20 to 25 pints in twenty-four hours is the average for the year, but with poor feeding it will fall much below this; occasionally a cow, soon after calving, will give 50 pints, but this is not common. A goat will give 6 to 8 pints.

### SUB-SECTION I.—MILK AS AN ARTICLE OF DIET.

Milk contains all the four classes of aliment essential to health. Being intended especially for feeding during growth, the proportions of nitrogenous substances and fat, as compared to sugar, are large.

*Average composition of Unskimmed Milk.*—A certain proportion between the casein, fat, and sugar must exist.

| | Per cent. Specific gravity, | | | Per cent. Specific gravity, | |
|---|---|---|---|---|---|
| | 1030. | 1026. | | 1030. | 1026. |
| Casein, . . . | 4 | 3 | Salts, . . . | ·6 | ·5 |
| Fat, . . . . | 3·7 | 3·9 | Total solids, | 13·3[‡] | 9·9 |
| Lactin, . . . | 5 | 3·9 | Water, . . | 86·7 | 90·1 |

The casein is by some supposed to be a combination of albumen with potash (Hoppe-Seyler).

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[*] Mil. Med. and Surg. Essays prepared for the U.S. Sanitary Com. 1864, p. 202.

[†] Naval Hygiene p. 112. In the American war, however, the anti-scorbutic effects of the dried vegetables were not found to be very great. I found that, in a sound raw potato, the amount of free and combined acid (reckoned as citric) was 0·4503 per cent.; and that in the preserved potato used in the Arctic Expedition (1875–6) it was 1·085; or in the ratio of 1 to 2·4. From this we find that 7 ounces of the preserved potato contained the equivalent of 31½ grains of citric acid, or one ounce of navy lime juice. The ration usually issued (2 to 4 ounces) is, therefore, too small, unless other antiscorbutics be given. (See report of Committee on Scurvy, Appendix, xiii. 365.) (F. de C.)

[‡] Wanklyn considers average country milk to contain 12·5 per cent. of solids, of which 3·2 parts are fat, and 9·3 are solids not fat. The Society of Public Analysis proposed, as a minimum for new milk, 9· per cent of solids not fat, and 2·5 of fat; for skim milk, 9·0 solids not fat;

In addition to casein, a small quantity of true albumen remains in solution after the casein has been thrown down, and there is also, according to Millon,* another albuminoid substance, which he calls lactoprotein. In cow's milk the amount of albumen is said to be 5·25 grammes per litre; the amount of lactoprotein is much smaller, but has not been very precisely determined.†

The amount of salts varies from ·5 to ·8 per cent., but seldom, if ever, exceeds 1 per cent. This is of importance in the detection of adulteration by salts. In poor milk the salts may be as low as ·3 per cent.

Milk is very largely used in some countries, especially in India and Tartary, where the use of the koumiss, prepared from mare's milk, has been supposed to prevent phthisis.

Milk varies in quantity and composition according to—*1st*, the age of cow; *2d*, the number of pregnancies, less milk being given with the first calf (Hassall); *3d*, to the age of the calf, being at first largely mixed with colostrum; *4th*, to the kind of feeding, beet and carrot augmenting the sugar;‡ *5th*, and remarkably, according to the race, some cows giving more fat (as Alderneys), others more casein (as the long-horns). The last portion of the milk given in milking is richest in cream (Hassall).

Wanklyn states that the proportion of solids is more stable, and never falls below 11·5 per cent. In Sweden, the milk of a herd of cows being analysed daily for a year, the solids never fell to 11·5, and only 4 times to 12 per cent. (Wanklyn).

The goat's milk is rather richer in solids (14·4 per cent.—Payen), and contains also a peculiar smelling acid (hircine or hircic acid). Specific gravity, 1032–1036.

Ass's milk is rather poorer in solids (9·5 per cent.—Payen). This is owing to a small amount of casein and fat; it is rich in lactin. The specific gravity varies from 1023 to 1035.

The buffalo milk is richer in all the ingredients.

Taking the total solids of cow's milk at only ten per cent. (specific gravity 1026), one pint (20 ounces) will contain, in round numbers—

| | | |
|---|---|---|
| Casein, | 262 | grains. |
| Fat, | 217 | „ |
| Lactin, | 341 | „ |
| Salts, | 42 | „ |
| Total, | 862 | |

or very nearly 2 ounces avoir. of water-free food.

To give 23 ounces of water-free food (or one day's allowance for an adult), rather more than 11 pints of milk, of specific gravity 1026, are necessary. For an adult this would be far too much water, and the fat would be in great excess. But for the rapid formation and elimination of the young, the water and fat are essential. It is a question whether, in old age, large quantities of milk might not be a remedy for failures in tissue formation and elimination.§

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* Comptes Rendus, t. lix. p. 396.

† Commaille (Comptes Rendus, Nov. 9, 1868) found creatinine in some putrid milk, derived, he thinks, from creatin. He admits also, after Lefort, that there is a little urea. He found also some organic acids, the nature of which is doubtful.

‡ Some observations of Dr Subbotin (Virchow's Archiv, band xxxvi. p. 561) on the milk of bitches, show a marked effect by food; the fat was much increased by meat; the casein was less affected; a large quantity of fat greatly lessened the secretion.

§ This was a point debated by Galen, so old is this suggestion. It is still undecided. Some old persons cannot digest milk.

## SUB-SECTION II.—ALTERATIONS OF MILK.

The cream rises in from four to eight hours; it is hastened by adding warm water, but its quantity is not increased (Hassall).

Milk alters on standing; it absorbs oxygen, and gives off carbonic acid; placed in contact with a volume of air greater than its own bulk, it absorbs all the oxygen in three or four days (Hoppe-Seyler). The carbonic acid is formed at the expense of the organic matter (probably casein—Hoppe-Seyler), and bodies richer in carbon and hydrogen are formed; fat increases in amount, and oxalic acid is said to be formed.

Subsequently lactic acid is formed in large quantities from the lactin; the milk becomes turbid, and finally casein is deposited. The cream which had previously risen to the surface disappears.

### *Milk given by diseased Cows.*

Milk from diseased animals soon decomposes; it may contain colostrum, or heaps of granules collected in roundish masses, pus cells, or epithelium, and occasionally blood. It then soon becomes acid, and the microscope usually detects abnormal cell forms, and casts of the lacteal tubes.

In cattle plague, it is said by Husson that the lactin lessens, while the nitrogenous matters are increased, and blood and aggregated granules are seen under the microscope. In foot-and-mouth disease the specific gravity rapidly falls (from 1030 to 1024), though this is not invariable; there are granular heaps under the microscope, and often blood or pus cells; Mr M'Bride says pus can be found for a month after recovery. Bacteria and small oval and round cells are common. Figures of the microscopical appearances are given in some very good papers on the subject in the *British Medical Journal*, Oct. 1869. The milk sometimes coagulates on boiling.

## SUB-SECTION III.—EXAMINATION OF MILK.

This is intended first to determine the quality. Put some of the milk in a long glass, which is graduated to 100 parts; a 100 centimetre or litre measure will do, or a glass may be specially prepared by simply marking with compasses 100 equal lines on a piece of paper, and gumming it on the glass. Allow it to stand for twenty-four hours in a cupboard secured from currents of air. By this means the percentage of cream can be seen, and the presence of deposit, if any, observed. There should be no deposit till the milk decomposes; if there be, it is probably chalk or starch.

The cream should be from $\frac{6}{100}$ths to $\frac{11}{100}$ths; it is generally about $\frac{8}{100}$ths; in the milk of Alderney cows it will reach $\frac{30}{100}$ths or $\frac{40}{100}$ths. The time of year (as influencing pasture), and the breed, should be considered.*

While this is going on, determine—

1. *The Physical Characters.*—Placed in a narrow glass, the milk should be

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* Mr Garside (Pharmaceutical Journal, Jan. 25, 1873) states that more cream is thrown up at a low than a high temperature; at 43° Fahr. there were $\frac{14}{100}$ths of cream; at 55° only $\frac{8.4}{100}$ths in the same milk. I have not found quite the same results, and on repeating the experiments, it is clear that great care is necessary. If the temperature of the milk alters (which is often the case with laboratory experiments at high temperatures), there are circulatory currents in the milk which greatly affect the rising of the cream; sometimes they hinder, and perhaps sometimes accelerate it. But if the milk is shielded from currents of air and from radiated heat, the amount of cream between the temperatures of 45° and 65° is practically the same. It is to secure it from currents of air that the graduated lactometer is ordered to be put in a cupboard. With regard to time, the cream has usually thoroughly risen in from four to six hours. In twenty-four hours it reads about $\frac{1}{10}$th less than at four hours, probably from condensation or aggregation of the fat particles.

quite opaque, of full white colour, without deposit, without peculiar smell or taste. When boiled it should not change in appearance.

2. *Reaction.*—Reaction should be slightly acid or neutral, or very feebly alkaline; if strongly alkaline, either the cow is diseased (?) or there is much colostrum, or carbonate of soda has been added.

3. *Specific Gravity.*—The specific gravity varies from 1026 to 1035. A very large quantity of cream lowers it, and after the cream is removed, the specific gravity may rise, under ordinary circumstance, about 2°.* The average specific gravity of unskimmed milk may be taken as 1030 at 60° Fahr., and the range is nearly 4° above and below the mean. It varies with temperature, so that in the tropics the medical officer will have to allow for this difference. The following are the relative degrees of a milk that shows 1030 at 60° Fahr., and 1031 at 39° Fahr., (maximum density-point of water):—

39° F. = 1031
60° F. = 1030
70° F. = 1029
80° F. = 1027·5
90° F. = 1025·8
100° F. = 1024·0

The addition of water is best detected by the specific gravity. At 60° Fahr. there is a loss of 3° for every 10 per cent. of water added. No doubt the method is not perfect, but its ease of application strongly recommends it.

4. *Examine chemically for the Amount of the Different Constituents*—

(*a*) *Total solids.*—Evaporate a known weight to dryness, and weigh. Calculate the percentage. The heat must not exceed 240° Fahr. As it is difficult to dry it thoroughly, the result is only approximative. Wanklyn recommends 5 C.C. to be employed, and the drying carried on in a water-bath for 3 hours at 212° Fahr.

(*b*) *Ash.*—Incinerate the dried solids, and weigh.

(*c*) *Casein.*—Take a weighed or measured quantity; add two or three drops of acetic acid, and boil. Add a good deal of water; allow to stand for twenty-fours hours; pour off the supernatant fluid; wash the precipitate well with ether at 80°; dry, and weigh. Calculate the percentage. It is difficult to entirely free it from fat. Wanklyn recommends the albuminoid ammonia process, as in the case of nitrogenous matter in water: 1 part of casein yielding 0·065 of ammonia.

(*d*) Evaporate the ether, and weigh the fat. Wanklyn recommends extracting the fat from the total dried solids by means of ether, evaporating, and weighing. This requires care, however, and the same result can be given by the employment of an instrument called a lactoscope, which measures the degree of transparency. The lactoscope of Donné has been lately improved by Vogel, and this simple plan can be recommended for ascertaining the amount of fat in milk.

Vogel's instrument consists of a little cup, formed by two parallel pieces of glass, distant $\frac{1}{2}$ a centimetre ( = ·1968 inches, say $\frac{2}{10}$ths of an inch) from each other, and closed everywhere except at the top, so as to form a little vessel; a glass graduated to 100 C.C., and a little pipette, which is divided to $\frac{1}{2}$ C.C., are also required. Water (100 C.C.) is placed in the measure, and 2 or 3 C.C. of milk (which should be at first agitated, so as to mix any separated cream) are added to it. The parallel glass cup is then filled with this diluted milk, and a candle placed about one metre from the eye (=39·37 inches) is looked at in a rather darkened room; if the flame of the candle is seen, the milk is poured back into the large measure; more milk is added to it, and it is poured again into the parallel glass, and the light is again looked at; the experiment ends when the contour of the light is completely obscured. The candle should be a good one, but the difference in the amount of light is not material. The percentage amount of fat in the milk is then calculated by the following formula (which has been determined by a comparison of the results of the instrument, and of chemical analysis): $x$ being the quantity of fat sought, and $m$ the number of C.C. of milk which added to the 100 C.C. of water suffice to obscure the light.

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* Dr Davies records a case where the specific gravity was 1024·6; there was 17 per cent. of cream, and the solids were 16·25. A case of this kind cannot mislead if the amount of cream is determined. Davies recommends that the specific gravity of the whey should be taken; he says it is very constant between 1026 and 1028.

In one sample I examined the specific gravity was 1020, and the cream $\frac{40}{100}$, the specific gravity of the skimmed milk was 1028·9. Another sample gave: specific gravity 1017·6, cream $\frac{60}{100}$; specific gravity of skimmed milk, 1032·75. Another sample (which purported to be the same as the last) gave a specific gravity of 1018·84, but the cream was only $\frac{4}{100}$; in this case the greater part of the cream had been removed, and about 50 per cent. of water added. (F. de C.)

$$x = \frac{23·2}{m} + 0·23.$$

If, for example, 3 C.C. of milk, added to the 100 of water, were sufficient to obscure the light, the percentage of fat is—

$$x = \frac{23·2}{3} + ·23 = 7·96 \text{ per cent.}$$

From this formula the following table has been calculated, which enables us to read off at once the percentage of fat :—

| C.C. Milk. | = | | Per cent. of Fat in the Milk. | C.C. Milk | | | Per cent. of Fat in the Milk. |
|---|---|---|---|---|---|---|---|
| 1 | to 100 of water | obscures the light = | 23·43 | 14 | to 100 of water | obscures the light = | 1·88 |
| 1·5 | ,, | ,, | 15·69 | 15 | | | 1·78 |
| 2 | ,, | ,, | 11·83 | 16 | | | 1·68 |
| 2·5 | ,, | ,, | 9·51 | 17 | | | 1·60 |
| 3 | ,, | ,, | 7·96 | 18 | | | 1·52 |
| 3·5 | ,, | ,, | 6·86 | 19 | | | 1·45 |
| 4 | ,, | ,, | 6·03 | 20 | | | 1·39 |
| 4·5 | ,, | ,, | 5·38 | 22 | | | 1·28 |
| 5 | ,, | ,, | 4·87 | 24 | | | 1·19 |
| 5·5 | ,, | ,, | 4·45 | 26 | | | 1·12 |
| 6 | ,, | ,, | 4·09 | 28 | | | 1·06 |
| 6·5 | ,, | ,, | 3·80 | 30 | | | 1·00 |
| 7 | ,, | ,, | 3·54 | 35 | | | 0·89 |
| 7·5 | ,, | ,, | 3·32 | 40 | | | 0·81 |
| 8 | ,, | ,, | 3·13 | 45 | | | 0·74 |
| 8·5 | ,, | ,, | 2·96 | 50 | | | 0·69 |
| 9 | ,, | ,, | 2·80 | 55 | | | 0·64 |
| 9·5 | ,, | ,, | 2·67 | 60 | | | 0·61 |
| 10 | ,, | ,, | 2·55 | 70 | | | 0·56 |
| 11 | ,, | ,, | 2·43 | 80 | | | 0·52 |
| 12 | ,, | ,, | 2·16 | 90 | | | 0·49 |
| 13 | ,, | ,, | 2·01 | 100 | | | 0·46 |

If, for example, 1 cubic centimetre of milk to 100 of water obscures the light, the percentage of fat is 23·43; if 8 cubic centimetres, added to 100 of water, are needed to obscure the light, the percentage is 3·13, &c.; so that in four or five minutes an analysis of the milk is made, as far as the fat is concerned.

The advantage of this is obvious, both in detecting the removal of cream, and in seeing if milk is rich in butter. Wanklyn states that 0·2 grammes of fat equal 1 gramme of cream.

(*e*) Determine the amount of lactin by the saccharometer, or by the copper solution.* To do this, take 10 C.C. of milk, add a few drops of acetic acid, and warm—this coagulates the casein with the fat; then make up to 100 C.C. with distilled water, filter, and put the filtered whey (which ought to be as clear as possible) into a burette. Take 10 C.C. of standard copper solution (see below), put it in a porcelain dish, and add 20 or 30 C.C. of distilled water; boil; as soon as it is in brisk ebullition drop in the whey from the burette; take care that the liquid is boiling all the time; continue the process until the copper is all reduced to red suboxide and no blue colour remains in the supernatant liquid; but stop before any yellow colour appears. Read off the amount of whey used, and divide by 10; the result is the amount of milk which exactly decomposes 10 C.C. of the copper solution. The 10 C.C. of the copper solution are equal to ·0667 grammes of lactin. The amount of lactin in the 10 C.C. of milk is then known by a simple rule of three; and the amount in 100 C.C. of milk is at once obtained by shifting the decimal point one figure to the right.

*Example*:—15 C.C. of diluted whey were required to reduce the 10 C.C. of copper solution; $\frac{15}{10} = 1{\cdot}5$ the amount of original milk; $0{\cdot}0667 \div 1{\cdot}5 = 0{\cdot}0445$ grammes of lactin in 1 C.C.; therefore $0{\cdot}0445 \times 100 = 4{\cdot}45$ per cent.

*Preparation of the Copper Solution.*—Take 34·64 grammes of pure sulphate of copper, and dissolve in about 200 C.C. of water; dissolve in another vessel 173 grammes of tartrate of soda and potash in 480 C.C. of solution of caustic soda (or potash, if the caustic soda, as is probable, is not in the surgery); mix slowly, and dilute with distilled water to one litre.

1 C.C. = 0·00500 grammes of glucose.
1 C.C. = 0·00667 grammes of lactin.

5. *Examine the Milk microscopically.*—The only constituents of milk are the round oil globules of various sizes in an envelope and a little epithelium. The abnormal constituents are epithelium in large amount, pus, conglomerate masses, and casts of the lacteal tubules. The added ingredients may be starch grains, portions of seeds, and chalk (round and often highly refracting bodies, with often a marked double outline, and at once disappearing in acid). Colostrum, occurring for three to eight days after the birth of the calf, is composed of agglomerations of fat vesicles united by a granular matter. Infusoria are sometimes found in milk, and fungi (*Oidium lactis* and *Penicillium*) are so almost invariably, if the milk has been kept.†

If milk is agitated with three or four volumes of carbon bisulphide, and then allowed to stand, the sulphide separates highly charged with an aromatic matter, which, on spontaneous evaporation, can be obtained as an unctuous imponderable residue, which possesses the aroma of the food of the animal (Millon).

### *Scheme for a Short Examination.*

As a medical officer is constantly called upon to examine milk, and will seldom have time to go thoroughly into all the points just noted, the following short scheme will be useful:—

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* Wanklyn recommends dissolving out the lactin from the solids (after the fat is removed) by means of alcohol, evaporating and weighing; then incinerating; the difference gives the amount of lactin. This seems on the whole less convenient for the medical officer than the copper test. Macnamara (Indian Medical Gazette, 1873) uses alcohol for extracting the lactin, but determines it by Fehling's test.

† Dr Willard of Cornell University notes the experience of Professor Law, who observed a peculiar ropy material in milk, and traced it to cows drinking stagnant water containing organisms similar to those found in the milk; a drop of this water, put unto good milk, soon developed these organisms. The cows were feverish. (Dr John Ogle, Journal of the Agricultural Society, Nov. 15. 1872; Lancet, Oct. 11, 1873.)

1. Put some milk into the long graduated glass for deposit, and for determining percentage of cream.*

2. Take physical characters, reaction, and specific gravity. Take specific gravity of the whey, if there be time to do this.

3. Determine fat by Vogel's milk-test.*

The comparison of the specific gravity, and the amount of cream which rises, or of fat, will be found to give, in conjunction with the physical characters, a very good idea of the quality of the milk.

### SUB-SECTION IV.—PRESERVATION OF MILK.

1. Boiled, the bottle quite filled, and at once corked up and well sealed, the milk lessens in bulk, and a vacuum is formed above. It will keep for some time. A little sugar aids the preservation. If the heat is carried in a close vessel to 250° Fahr., the milk is preserved for a very long time, even for years; the butter may separate, but this is of no consequence.

2. Sulphurous acid passed through it, or sulphite of soda added. This may be done after boiling.

3. A little carbonate of soda and sugar added, with or without boiling. This will keep for ten days or a fortnight.

In the market are—milk in tins, preserved in the usual way by exclusion of air, concentrated milk mixed with sugar, and desiccated or dried milk. This last is milk carefully dried at a low temperature, with a little sugar. Dissolved in water, it forms an excellent milk. (See Concentrated Food p. 276).

The preserved liquid milk often has the butter separated; if so, it may be spread on bread. It is not easy to remix it with milk, but it is said that the separation may be prevented by adding a little yolk of egg.

### SUB-SECTION V.—ADULTERATIONS.

1. *Water.*—This is extremely common, and is, in fact, generally the only adulteration; it is best detected by specific gravity or evaporation. Wanklyn suggests the amount of ash as a good test of watering; the normal ash being, according to him, about 0·73 per cent.

2. Starch, dextrin, or gum, to conceal the thinness, and the bluish colour produced by water. Not a common adulteration. Add iodine at once for starch; boil with a drop of acetic acid, and add iodine for dextrin, or add acetate of lead and then ammonia, a white precipitate falls.

3. Annatto or turmeric is added to give colour. Liquor potassæ at once detects turmeric. By boiling the milk, the colouring matter remains in the serum.

4. Emulsions of seeds (hemp or almond), added; this is uncommon. Boil. The albumen of the seeds coagulates; the milk will not mix with tea. Hemp seed gives an unpleasant odour to the milk (Normandy).

5. Chalk, to neutralise acid, and to give thickness and colour. Let it stand for deposit; collect and wash deposit, and add acetic acid and water; after effervescence filter, and test with oxalate of ammonium.

6. Carbonate of sodium. Very difficult of detection unless the milk be

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* Macnamara (Indian Medical Gazette; 1873) finds that the cream is not very useful in India as a test, the rapid coagulation of the milk preventing it rising; similarly Vogel's test does not give satisfactory results. It would, therefore, be necessary to determine the constituents by the chemical methods if possible.

alkaline. Determine the ash, and see if it effervesces; if so, either some carbonate has been added, or if the soda have united with lactic acid, this will be converted into carbonate, and enough lactic acid to give an effervescing ash does not exist in good milk.

7. Milk is often boiled to preserve it; it may then take up from the vessel lead, copper, or zinc, if these metals are used.

*Cream* is adulterated or made with carbonate of magnesia, tragacanth, and arrowroot. The microscope detects the latter, and particles of carbonate of magnesia (round) can also be seen and be found to disappear with a drop of acid. It is also said that yolk of egg is added both to cream and milk.[*]

### SUB-SECTION VI.—EFFECTS OF BAD MILK.

Professor Mosler[†] has directed attention to the poisonous effects of "blue milk,"[‡] that is to say, milk covered with a layer of blue substance, which is in fact a fungus, either the *Oidium lactis* or *Penicillium*, which seems to have the power, in certain conditions, of causing the appearance in the milk of an aniline-like substance.[§] The existence of this form of fungus was noted by Fuchs as long ago as 1861. Milk of this kind gives rise to gastric irritation (first noted by Steinhof); and, in four cases mentioned by Mosler, it produced severe febrile gastritis.

Milk which is not blue, but which contains large quantities of Oidium, appears from Hessling's observations[‖] to produce many dyspeptic symptoms, and even cholera-like attacks, as well as possibly to give rise to some aphthous affections of the mouth in children.

Milk contaminated with pus from an inflammed udder, or an abscess on the udder, will give rise to stomatitis in children, and to aphthæ on the mucous membrane of the lips and gums.[¶]

There has been much discussion whether the milk from foot-and-mouth disease in cows (*Eczema epizootica*) can cause affections of the mouth, or give rise in human beings to any disease similar to that of cattle. Pigs can certainly get the disease from the milk of the cow; sheep and hares, which also have the disease, perhaps got it from the saliva on herbage. In men the evidence is discordant, and in a great measure negative,[**] still there are some striking cases, which seem to me sufficient to prove that disease of the mouth (aphthous ulceration, general redness, diphtheritic-like coating, swollen tongue) and sometimes, though rarely, an affection of the feet may occur.[††] Some positive evidence has been adduced by Professor M'Bride[‡‡], Gooding,[§§] Hislop,[‖‖]

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[*] Mr Bottle, Pharmaceutical Journal, February 1873.

[†] Virchow's Archiv, band xliii. p. 161 (1868).

[‡] Blue milk is given by feeding cows with some vegetable substances, as *Myosotis palustris, Polygonum aviculare, and Fagopyrum, Mercurialis perennis*, and other plants (Mosler); but this is different from the blue colour referred to above.

[§] Erdmann (Journal für Prakt. Chem., xcix. p. 385, quoted by Mosler) has discovered that vibriones have the power of producing aniline-colouring matter from protein substances.

[‖] Virchow's Archiv, band xxxv. p. 561. See also my Report on Hygiene, Army Medical Report, vol. vi. p. 385.

[¶] See a good case by Dr Fagan (British Med. Journal, Nov. 13, 1869).

[**] See Dr Thorne's paper in the Report of the Medical Officer to the Privy Council, p. 294, and Mr Simon's remarks on it, p. 62. Also my Report on Hygiene, Army Med. Blue Book, vol. x. p. 223. Dr Lawson Tait's negative evidence against it is exceedingly strong (Medical Times and Gazette, October 1869); the disease was all round, and the milk was used, yet not a a case occurred which could be referred to it. See also Whitmore's evidence in Marylebone (British Medical Journal, Oct. 1869).

[††] A case of the foot being involved is recorded by Mr Amyot (Med. Times and Gazette, Nov. 4, 1871).

[‡‡] Brit. Med. Journal, Nov. 18, 1869. An anonymous writer in the same Journal, Sept. 1869, adduces also a few doubtful cases (p. 327), though his evidence is otherwise negative.

[§§] Medical Times and Gazette, Jan. 1872.

[‖‖] Edin. Med. Journal, Nov. 1869.

Latham,[*] and Briscoe.[†] I have also had cases related to me by two medical friends, which seemed quite clearly cases of the disease. It is, of course, possible that some pus or blood from abscesses on the teat or udder may have got into the milk, but it is unlikely that this should have been overlooked.

A peculiar disease has several times prevailed in the Western States of America, which is caused by the unboiled (not by the boiled) milk of cows affected with the "trembles," which is supposed to be produced by the cows feeding on *Rhus Toxicodendron*. In children who get this milk-sickness,[‡] there is extreme weakness, vomiting, fall in bodily temperature, swollen and dry tongue, and constipation. Boiling appears to remove the hurtful qualities of the milk.[§]

Milk may also be a means of conveying the poisons of enteric fever and of scarlet fever. In the former case, it has probably usually arisen from the watering of the milk with foul water containing the agent,[||] but it may possibly have in some cases arisen from the typhoid effluvia being absorbed by the milk, as in the case at Leeds mentioned below. The scarlet fever poison has appeared to get into the milk from the cuticle or throat discharges of persons affected with scarlet fever, who were employed in the dairy while ill or convalescent.[¶]

## SECTION XII.

## BUTTER.

As an article of diet, butter supplies to most people the largest amount of fat which they take. Many persons take from 1½ to 2 oz. daily, if the butter used in cooking be included, and the average amount for persons in easy circumstances is 1 oz. daily. Butter appears to be easily digested by most persons, except when it is becoming rancid. It then causes dyspepsia and diarrhœa, and as a rule it may be said that decomposing fats of all kinds disagree.

### Composition and Examination.

1. The average amount of water varies from 5 to 10 per cent., but may be higher, even in genuine butter. Hassall has found as much as 15½ per cent. in fresh, and 28½ per cent. in salt butter; Wanklyn records 23·6 per cent. in fresh butter supplied to Paddington workhouse. The retail dealer, by beating up the butter in water, endeavours to increase the amount. This can be detected by evaporation in a water bath; if the quantity of water be very large, melting the butter will show a little water below the oil. An unusually small amount of water is suspicious (Angell), as suggestive of the presence of foreign fat.

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[*] British Medical Journal, May 1872.

[†] British Medical Journal, Oct. 1872.

[‡] Cases of severe diarrhœa have occurred from the use of milk from goats that had fed on Euphorbium; this has been observed at Malta.

[§] Boston Med. and Surg. Journal, January 1868, and Transactions of the Kentucky State Medicine Society, quoted in Medical Times and Gazette. There have been many instances in the last half century, and they have all been collected by Hirsch.

[||] See Ballard's exhaustive analysis of the Islington epidemic, which was traced decidedly to the use of watered milk (Medical Times and Gazette, Nov. 1870, and reprint); a somewhat similar case is recorded by Dr Taylor of Penrith (British Medical Journal, Dec. 1870). There have been four cases lately—one at Moseley, near Birmingham, traced by Dr Ballard; one at Leeds, by Dr Robinson (Brit. Med. Journal, Jan. 18, 1873); one at Armley, near Leeds; and one at Parkhead, in Glasgow, recorded by Dr Russell (Med. Times and Gazette, March 15, 1873). The evidence is very strong in all the cases.

[¶] A remarkable case is recorded by Professor Bell of St Andrews (Lancet, Oct. 29, 1870), and another by Dr Taylor of Penrith (British Medical Journal, Dec. 1870). See also Dr Buchanan's Report of the outbreak at South Kensington, apparently traceable to cream.

2. *Casein.*—All butter contains some casein, as some milk is taken up with the cream. The best butter contains least. The amount can be told roughly by melting in a test tube. The casein collecting at the bottom does not exceed one-third of the height of the contents of the tube in the best butter, or between one-third and one-half in fair butter. In bad butter it may reach to more than this. A better plan is dissolving the fat by ether, washing and then weighing the remainder; the casein then weighs from 5 to 3 grains in every 100 of very good butter. In bad butter it is much more than this.

The rancidity of butter is chiefly owing to changes in the fat, produced apparently by alterations in the casein, and therefore the greater amount of casein the more the chance of rancidity.

3. *Fat.*—The fat amounts to from 86 to 92 per cent. of the butter. Butter oil consists of volatile fatty acids (butyric, caproic, caprylic, and capric), and of non-volatile acids (stearic, palmitic, and oleic), all combined with glycerine. In examining it, the butter should be melted in a beaker-glass, placed in hot water, and the fat should be poured off the casein, and allowed to cool. It then forms a solid and usually yellow mass, with the characteristic smell of butter, and should be further examined as follows :—

(*a*) *Smell, taste, and colour of this recongealed fat.*—The smell and taste are very characteristic, and with a little care the quality of butter, and even the presence of some adulterations, such as mutton fat, can be determined. The colour is usually yellowish-white; other fats are white, but annatto may be used for colouring them, or true butter may be white, so that the coloration is not a safe test.

(*b*) *Examine the recongealed fat with the microscope.*—Butter shows nothing but oil globules; lard and other fats often, but not always, contain acicular and stellate crystals of margaric (really a mixture of palmitic and oleic) and stearic acids as pointed out by Hassall. Starch and other impurities may be sometimes seen and are tinged by iodine. The casein left after the fat has been poured off should be also examined, and starch, membrane, or other impurities may be seen in it. The polariscope may be used to bring out more strongly the stellate stearic acid crystals, if present. Angell and Hehner point out that even genuine butter sometimes shows crystals after melting and recongealing; they therefore think the presence of crystals ground for apprehension only, showing no more than that the fat has been melted.

(*c*) *Determine the melting-point of the fat after separation from the casein.*—Some of the fat should be put into a wide tube, and placed in an evaporating dish with water; a thermometer should be in the water and another in the fat. Raise the temperature of the water very gradually; remove the lamp from time to time, so that the temperature of the fat may rise slowly. Note the temperature when it begins to melt; when it is completely melted; and when (after removal from the warm water) it begins to recongeal, and becomes quite solid. The melting-points are, however, not constant, owing to the variable amounts of stearin and oleine, and the volatile fatty acids, but still they run within tolerably narrow limits.

The temperature when the fat is completely melted appeared to be the most marked point in my experiments. The butter oil is most easily melted, and requires the greatest amount of cooling before recongealing; usually there is a difference, often 12° to 15°, between the points of commencing and completed fusion. The determination of the melting-point is, however, certainly more useful in proving that the butter has only slight admixture, than in proving complete purity; *i.e.*, the presence of a small quantity of lard or beef dripping would not raise the melting-point sufficiently for detection. In the case of beef dripping, also, the melting-point is rather close to that of butter.

*Temperature*[*] *of Melting and Solidifying.*

| | Fusion. | | Solidification. | |
|---|---|---|---|---|
| | Commencing. | Completed. | Commencing. | Completed. |
| | Degrees. | Degrees. | Degrees. | Degrees. |
| Butter oil, | 65–68 | 80–90 | 70–80 | 60–82[†] |
| Lard, | 76–80 | 100–115 | 90–100 | 71–75 |
| Beef dripping, | 68–85 | 100–120 | 90–100 | 72–76 |
| Mutton dripping, | 86–100 | 140–150 | 120–130 | 86–92 |
| Palm oil,[‡] | 81–92 | 110 | 88 | 69 |

(*d*) Angell and Hehner ("Butter: its Analysis and Adulterations," 2d. ed. 1877) recommend examining the sinking-point, by means of a little glass bulb weighted with mercury to 3·4 grammes; the mean sinking-point of 24 genuine butters was 35°·5 C. (96° Fahr.), ranging from 34°·3 C. to 36°·3 C. (93°·7 Fahr. to 97°·3 Fahr.) The butter is melted and poured into a test-tube and allowed to cool; as it cools a slight conical depression appears on the surface; this must be rendered even by remelting the upper part. If other fats are present the depression is much more marked. The tube, with the bulb on the top of the fat, is then plunged into a large beaker of water, which is gradually heated until the bulb sinks, the temperature of sinking being noted by means of a thermometer placed in the water.[§]

(*e*) Another method, recommended by the same chemists, consists in determining the percentage of fixed fatty acids, which seems to be pretty constant in butter fat, forming about 87·3 per cent. of its weight; 88·5 being adopted as a maximum, whereas most other fats give about 95·5 per cent.,—the difference in butter being made up by volatile fatty acids. The plan employed is to saponify the fat by boiling with caustic potash and water, to decompose the soap with hydrochloric acid, filter and wash with boiling water, and then weigh the fatty acids remaining undissolved on the filter. The saponification is much facilitated by commencing the process with methylated spirit, as suggested by Mr Turner, the public analyst of Portsmouth.

(*f*) The specific gravity of butter-fat has also been suggested by Mr Bell as a good means of determining purity. He melts the fat at 100° Fahr., and weighs in a specific gravity bottle. He shows that the specific gravity of ordinary fats varies between 902·83 and 904·56, whilst that of butter-fat rarely falls below 910, generally ranging between 911 and 913. (*Pharmaceutical Journal*, July 22, 1876.)

4. Salt is added to all butter. In fresh butter it should not be more than ·5 to 2 per cent. (8 grains per ounce); in salt butter, not more than 8 per cent. (35 grains per ounce). To determine the salt, wash a weighed portion of butter thoroughly with cold distilled water, and determine the chloride of sodium by nitrate of silver (see page 76). Dr Tidy recommends incineration and weighing the residue; his limit is 7 per cent.

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[*] I have made a considerable number of experiments on the melting-point and solubilty in ether, and on the whole attach more importance to the melting-point than to the solution in ether.

[†] It is rare for butter oil to be completely solid at 82°, but I once found it so in an undoubtedly pure butter, made during the winter on a gentleman's private farm. But usually butter is not solid till 68° or 65°.

[‡] These numbers were given to me by my friend Dr Campbell Brown of Liverpool, who has published a very good scheme for the examination of butter, of which I have made use.

[§] Hassall employs a converse plan, using a float instead of a sinker, the temperature at which it rises to the surface being noted; this generally occurs about 2° Cent., or 5°·6 Fahr. lower than the sinking-point above mentioned. Other plans have been proposed by Dr Tripe, Mr Heisch, Dr Redwood, and Mr Bell. Mr P. Duffy has pointed out the curious fact that pork, mutton, and beef fats have two or three allotropic conditions, with different melting-points.

By this method the amount of water, casein, oil, and salt will be determined, and the quality of the butter oil will have been examined.

### *Scheme for a Short Examination.*

1. Determine quality by the taste and smell of the whole butter, and of the melted, poured off, and recongealed fat.*
2. When melting for the fat in a tube, notice approximate amount of casein.
3. Determine the sinking-point by Angell's plan, or the floating-point by Hassall's.
4. Examine butter and recongealed fat with microscope, and add a weak solution of iodine to test for starch.
5. If time and means allow, determine the percentage of fixed fatty acids in the butter fat, by Angell and Hehner's method, or
6. Determine the specific gravity by Bell's method.

### *Adulterations.*

Butter is supposed to be frequently adulterated with lard, and with beef, mutton, and horse fat, and with vegetable oils. I have examined many specimens without getting satisfactory evidence of this.† In a process lately devised by Mège-Mouries,‡ fresh beef suet is melted in warm water with carbonate of potash and portions of fresh sheep's stomachs. The fat thus separated from the cellular tissue is cooled and subjected to hydraulic pressure, when the oleo-margarine is separated from the more solid stearine (which is used for candle-making), and mixed with milk and with a little of the soluble matter obtained by soaking cows' udders in milk, and with annatto, and is then churned. Now, this process is so complicated that it would not pay a dishonest tradesman to do it, and it could only be practised on a large scale. The sinking point and the determination of the amount of fixed fatty acids would probably detect this.§

Potato or other starches are sometimes added. It is a rare adulteration, and is at once detected by iodine, either at once or after melting. Gypsum and sulphate of barium have been added, it is said; this must be very rare, and be at once detected by melting and pouring everything off the insoluble powder, or by incinerating. Annatto is frequently used to colour butter.‖

*Preservation of Butter.*—Pouring water which has been boiled over butter will keep it for some time; but a better plan is one discovered by M. Bréon,¶ viz., water acidulated slightly (3 grammes to 1 litre) with acetic or tartaric acid, is added, and the whole is placed in a close-fitting vessel. Sugar also has a preservative effect, especially when mixed with a little salt.

## SECTION XIII.

## CHEESE.

*As an Article of Diet.*—It contains a very large amount of nitrogenous matter in small bulk (p. 195), and as it is agreeable to the palate, it must be an excellent food for soldiers in war. About ½ ℔ contains as much nitrogenous substance as 1 ℔ of meat and ⅓ of a ℔ as much fat. It does not, however, keep well in warm climates.

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* Butter becomes rank and bad, by the cream being allowed to become sour before churning in consequence of dirty vessels; it is a good plan to stir up the cream from time to time.

† More recent investigations by the later methods of analysis have shown that it does occur from time to time.

‡ Pharmaceutical Journal, Oct. 1872.

§ A substance from New-York has lately made its appearance in the market under the name of Butterine; it appears to be a wholesome fat, and as long as it is sold honestly as a substitute for butter, but not as genuine butter, its introduction will probably be a boon to many on account of its cheapness.

‖ Angell and Hehner record two cases of adulteration by mixing with milk.

¶ Payen. Des Subst. Alim. 4th ed. p. 179.

*The quality* is known by the taste. The only adulteration is from substances to give weight. Starch is chiefly employed, and can be detected at once by iodine. There is usually about 5 or 6 per cent. of salt.

Sulphate of copper and arsenious acid are sometimes used to destroy insects; the rind is then the most poisonous part. Copper is detected by ammonia or potassium ferrocyanide. Arsenic by any test (Reinsch's or Marsh's). Sometimes cheese becomes sour, particularly if made from sheep's milk, and may cause diarrhœa.

The *Acarus domesticus*, *Aspergillus glaucus* (blue and green mould), and *Sporendonema casei* (red mould), form during decay. During decay the fat augments at the expense of the casein; leucin is produced, and valerianic and butyric acids. Lactic acid is also often produced from the lactin of the milk contained in the cheese. The aroma of cheese partly arises from this decomposition, and the production of volatile acids.

## SECTION XIV.

## EGGS.

It is needless to say anything of eggs as an article of diet; they contain albumen and fat in very digestible forms.

*Composition and Choice.*—An egg weighs from 600 to 950 grains, or even more; the average weight is about two ounces avoir.; 10 parts are shell, 60 white, and 30 yolk; the white contains 86 per cent. of water; the yolk 52 per cent.; 100 grains of egg, therefore contain—

| | | |
|---|---|---|
| 10 | grains | shell. |
| 22·8 | „ | albumen and fat. |
| 67·2 | „ | water. |
| 100·0 | | |

If an egg weighs two ounces, it contains nearly 200 grains of solids; this is a convenient number to remember, as 100 grains correspond to 1 ounce.

For choice, look through the egg; fresh eggs are more transparent in the centre, old ones at the top. Dissolve 1 ounce of salt in 10 ounces of water; good eggs sink; indifferent swim. Bad eggs will float even in pure water.

*Preservation.*—Eggs are packed in sawdust or salt, or are covered with gum or oil, or placed in lime-water, with a little cream of tartar.[*] Boiling for half a minute also keeps them for some time; in fact, anything which excludes air.

The lime-water gives them, it is said, a peculiar taste, and makes the albumen more fluid.

## SECTION XV.

## CONCENTRATED AND PRESERVED FOOD.[†]

For the military surgeon this subject is so important, that it is desirable to put the chief facts under a separate section.

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[*] It is said that covering them with a solution of bees-wax in warm olive oil (⅓ of bees-wax ⅔ds of olive oil) will keep them for two years.—*Chemical News*, August 1865. p. 84.

[†] Dr Letheby informs us, that from 1800 to 1855 there were 177 patents taken out for drying and preserving food. Of these 26 were for drying the food, 31 for excluding atmospheric air, and 8 for giving an impervious coating.

It is obvious how important it must be in time of war to have a food which may be at once nutritious, portable, easily cooked, and not liable to deterioration. Lind's sagacious mind long ago saw this, and he strongly urged the advisability of having on board ship prepared food of this kind. It must be remembered, however, that a man must get his 260 to 300, or even 350 grains of nitrogen, and 8 to 12 ounces of carbon, in each twenty-four hours, besides some hydrogen and salts. The work of the body when in activity cannot be carried on with less ; and at present these elements cannot be presented to us in a digestible form in a smaller bulk than 22 or 23 water-free ounces. Concentration at present cannot be carried beyond this, and practically has not really been carried to this point. Life, however, and vigour may for some days be preserved with a much less amount; and I have reduced the total amount of food to 11 water-free ounces daily, with full retention of strength for seven days, though the body was constantly losing weight. For expeditions of three or four days, if transport were a matter of great difficulty, soldiers might be kept on 10 or 12 ounces of water-free food daily, provided they had been fully fed beforehand, and subsequently had time and food to make up the tissues of their own body, which would be expended in the time, and would not have been replaced by the insufficient food.

When we inquire into the concentrated foods now in the market, some of which profess to supply all the substances necessary for nutrition, we find them not very satisfactory. They are often not so concentrated as they might be, or are deficient in important principles, or are disagreeable to the taste.

*Dried Meat.*—Meat dried at a very low heat has been brought into the market by Verdeil. It has lost the greater part of its water, is hard, and requires very careful cooking, but is believed to be nutritious when well prepared.

Messrs M'Call of London have also prepared an excellent dry meat; it is sold in packets, each of which weighs 4 oz., and is intended for one meal. It contains salt and pepper, and 12 per cent. of water.

*Hassall's Flour of Meat.*—Good fresh meat, freed from visible fat, is carefully dried at a very low temperature, and is pulverised by machinery, so that a very fine smooth powder is formed. This is mixed with about 8 per cent. of arrowroot, 2½ per cent. of sugar, and 3 per cent. of a mixture of salts, pepper, spices, and colouring matter. The object of the arrowroot is to assist its suspension in water. From an analysis of 3 samples of the commercial flour of meat, I found the average to be in 100 parts—water, 12·68; fat, 10·99; salts, 3·82; and nitrogen, 8·81 (=nitrogenous compounds, 55·5); the rest is made up of arrowroot, spices, sugar, &c. The free acidity, taken as lactic acid, is 1·8 per cent. As this flour of meat contains albumen and fibrine in a condition well adapted for nutrition, it is probably more suited than Liebig's extract for a diet of long continuance. I have tried some experiments with it, and found that, when given with bread alone, it did not nourish properly. Two gentlemen, who lived on it and bread for some days, both became indisposed, and there was great dyspepsia, evidently imperfect digestion, with, in both cases, an eruption of acne. When to the same diet a larger amount of fatty and vegetable foods were added, without any increase in the meat or bread, the effect on health was described by both observers as perfectly marvellous; all symptoms of illness disappeared, and with this proper admixture of foods, Hassall's flour of meat answered admirably.*

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* I have seldom been more impressed than with these experiments; the evident difficulty in digestion of Hassall's food by itself, and in its perfect digestibility and evident nutritive power when there was admixture of vegetables and carbo-hydrates and fat, convinced me of the im-

Hassall's flour of meat keeps very well; but if the open tins are exposed to the air, after several months it slightly changes colour, and then acquires a peculiar odour. Subsequently it decomposes. But if well fastened, it will keep for a very long time. It will certainly be a valuable addition to the resources of the military surgeon.

Under the terms *Tasajos* and *Charqui*, two kinds of meat are prepared in South America; it is probable that these terms have not always been used in the same sense. According to Mr Bridges Adams, Tasajos is meat cut in thin slices, dipped in brine, and then partially dried. Charqui is thin strips of muscular fibre from which the fat is removed, dried rapidly by sun heat, and sprinkled with maize. The salted dried meat (Tasajos), analysed by Hassall, gave from 29 to 56 per cent. of water; 15 to 41 per cent. of nitrogenous substances; 3 to 12 of fat, and 11 to 20 of salts.

The dried meat of the Kaffirs (beltong) is very much the same; great hunks of beef are sun-dried, and remain undecomposed for a long time. So also in Egypt the meat is dried by exposure to the sun and north wind.

The Pemmican of the Arctic voyagers is a mixture of the best beef and fat dried together, and is an excellent food, though rather expensive. Sugar is sometimes added, and sometimes raisins and currants; the latter would be a very desirable addition where there was a deficiency of vegetable food. For analysis of pemmican see page 195.

Liebig's *Extractum Carnis* is the juice of meat extracted on the following plan:—Every particle of meat is separated from fat and tendons, and is then subjected for some time to a moderate heat; a viscid dark extract at last collects, which contains the salts, creatin, and other organic nitrogenous substances. Mixed with warm water, this extract gives a highly agreeable and nutritious beef-tea or mutton broth. One ℔ of mutton gives about two-fifths of an ounce of extract. It has the remarkable quality of not decomposing; Liebig had some for fifteen years in a bottle loosely stoppered.

There are now numerous samples of *Extractum Carnis* in the market, prepared in South America and Australia. The majority have an almost identical composition. I have analysed five different kinds, and there are other analyses by Apjohn and Hassall. Two of my five samples were obtained from the Fray Bentos Company, the others from Australia, Buenos Ayres, and Monte Video. The average amount of water (using round numbers) was 16 per cent.; of ash, 20 per cent.; of nitrogen, 8 per cent.; the lowest being 6·6, and the highest 10·14. All had an agreeable acidity; the average quantity was equal to 7 grains of free lactic acid (assuming that acid to be the sole cause of the acidity, which is not certain), and in addition there was combined lactic acid equal to 5½ grains. In all these respects the several extracts were very similar. There are some other extracts in the market, which are less rich in salts and more watery, but containing almost as much nitrogen; gelatine appears to have been added to these.

When Liebig's extract is taken during fatigue, it is found to be remarkably restorative, increasing the power of the heart, and removing the sense of fatigue following great exertion. Mixed with wine, it has been employed with great success in rousing men in collapse from wounds. As, however, the nitrogenous compounds in the *Extractum* are not in the form of albumen or fibrine, but of other compounds (creatine, extractives soluble in water and alcohol), it has been supposed that the nitrogen is not capable of being employed in the nutrition of muscles or gland-cells, and, in fact, that the

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mense importance of attending to these points in cases of sickness. I feel sure that in many cases, by adhering too closely to one class of diet, we must do injury.

*Extractum Carnis* does not represent a true nutritive albuminate. Liebig considered it to be a condiment which increases the power of the stomach to digest vegetable food; and Hörschelmann,* who does not consider it a substitute for meat, yet thinks that it aids in digesting hard meat, and that the meat ration can be lessened when it is used. By some its action has been compared to that of tea and coffee, but there does not appear to be any close parallel. By supplying lactic acids and flavouring matters and potash salts, it must aid nutrition, even if we suppose that the nitrogenous principles are useless, which cannot be considered as yet proved. It has been stated by Kemmerich† that the potash salts increase at first the power of the heart, but afterwards paralyse it, and he believes that large quantities of Liebig's extract may thus be injurious. Bunge‡ has repeated the experiments, and finds that Kemmerich has much overstated the effects, and that to paralyse the heart enormous doses would be necessary. There are about 15 grains of potash salts in 100 of extract, and Bunge has calculated that if the quantity which kills a rabbit, increased for size, would kill a man, no less than 225 grammes or 3471 grains would be necessary, which would be equivalent to putting the poisonous dose of potash at only 50 grammes (771 grains); the extract could not therefore do harm, even if taken in most unusual doses.

When taken in very large doses, the extract (like large quantities of meat) does sometimes cause heaviness and torpor, and this has been ascribed to the potash salts, but it may be a question whether it is not owing to the excess of the nitrogenous extractive matter.§

About 230 grains of extract in one pint of water are nearly equal to a pint of beef-tea made from $\frac{7}{10}$ths ℔ of fresh beef; $\frac{3}{4}$th ounce of extract in one pint are equal to a pint made from 1 ℔ of fresh beef. There is, however, a general opinion that the extract beef-tea is not so good as that made at once from fresh beef; a mixture of the two is well spoken of.

It seems probable, though proof has not been given, that Liebig's extract is an anti-scorbutic.

The "concentrated beef-tea" is beef-tea and the juices of the compressed beef mixed and evaporated. This is a highly nutritious substance, and most useful to the army surgeon. Mixed with wine, and given as soon as possible after wounds are received, in the time of shock and collapse, it was found in the Austrian army (in 1859) to save the lives of many wounded men, and the experience of the Federal American army is to the same effect (Hammond). *Extractum Carnis* is now made also by pressure without heat.

*Extract of Mutton.*—An Australian extract of mutton is now sold, which is more solid than Liebig's extract, and differs from it in containing much fat. It is a very good preparation.

*Bellat's Extract of Meat.*‖—In making this extract, the meat, deprived of fat and tendons, is cut up very fine, and exhausted with cold water; the residue is vapour-heated in hermetically-sealed vessels, and is then heated with its own weight of water and a proper quantity of bone to 194° Fahr. for six hours; it is subsequently pressed in an hydraulic press, mixed with water and cooked vegetables. To this mixture the cold-water extract is then added, and the whole is heated to clarify it, and is then filtered. It is subsequently evaporated to the consistence of thick honey, and packed in metal boxes, from which the air is excluded. A little less than an ounce (25 grammes) in 1¾ pint (1 litre) of water makes a good beef-tea.

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* Schmidt's Jahrb. 1872, Jan., p. 21.

† Zeitsch. für die ges. Phys., band ii. p. 49, 1869. See my Report on Hygiene in the Army Med. Department Blue Book, vol. ix. p. 256, for an abstract and discussion.

‡ Zeitsch. für die ges. Phys., band iv. p. 234.

§ Two gentlemen at my request lived for four days on Liebig's extract and bread. One lost weight, but was otherwise healthy; the other became indisposed and gained weight, as if excretion were interfered with. These symptoms were at once removed by the addition of fats and starches to the same diet, as in the analogous case noticed as occurring in the experiments with Hassall's dried meat.

‖ Poggiale, Rec. de Mem. de Med. Milit. 1868, Auvril, p. 268.

*Edward's patent desiccated soup* consists of a mixture of beef and vegetables; it is easily prepared by boiling in water, about an ounce to a pint of water. It was well spoken of in the Ashantee war.

*Meat Biscuits.*—These biscuits, or powders, for they are generally powdered and sold in canisters, are formed by mixing rich extract of meat with wheat flour, and drying. The biscuit of Mr Gail Borden, of Galveston, in Texas, contains equal parts of meat-extract and dried flour (made in a Papin's digester). A biscuit like this was very much used in the American war. The inventor represents that 10 ℔ will last a man for fourteen days, or at the rate of 11·2 ounces a-day, but this is clearly an exaggeration. The biscuit, after being powdered, is soaked in cold water for a few minutes, then boiled from twenty to thirty minutes.

Meat bisuits can be made in a very simple way, by mixing together, cooking, and baking 1 ℔ flour, 1 ℔ meat, ¼ ℔ fat (suet), ½ ℔ potatoes, with a little sugar, onion, salt, pepper, and spices. A palatable meat bisuit, weighing about 1¼ ℔, containing 10 to 12 per cent. of water, is then obtained, which keeps quite unchanged for four months.

*Pea Sausage.*—In the Franco-German war the Germans made great use of a pea sausage, made by mixing pea-flour and fat pork, with a little salt. I found it to contain, in 100 parts, 16·2 of water, 7·19 of salts, 12·297 of albuminates, 33·65 of fat, and 30·663 parts of carbohydrates. It is ready cooked, but can be made into a soup. It was much relished for a few days, but the men got eventually tired of it, and in some it produced flatulence and diarrhœa.

*Flour Sausages.*—A mixture of pork and wheat flour has been used in the same way.

*Maize and Beef.*—The Germans in 1870 made also use of a mixture of maize and beef, which appears to have been much liked.

*Dried Cerealia.*—Many flours, if well dried, will keep for a long time. Hard's "farinaceous food for infants" is wheat flour baked. Denham's "farinaceous food" is composed of 3 parts wheat flour and 1 part of barley, dried at a heat of 200° Fahr. It loses from 26 to 30 per cent. in weight. The Russian Government formerly used a cake composed of a mixture of oatmeal and malt (2 parts to 1); it was baked, and formed an agreeable article of food. When placed in water in a warm place, a slight fermentation goes on, and a kind of beer is produced. I have kept these cakes unaltered for more than a year. There are now in the market different kinds of malt biscuit and granulated malt food. Liebig's food for infants is composed of equal parts of wheaten flour and malt flour mixed with a little carbonate of potash and cooked with 10 parts of milk. The wheat and malt flour are now usually cooked, and sold in powder ready to be boiled with the milk.

*Dried Bread.*—In addition to biscuit already described, bread has been partially dried by being pressed in an hydraulic press (method of Laignel). Much water flows out, but when taken out the bread still feels moist. In a day or two, however, it becomes as hard as a stone, and in a year's time will be found good and agreeable. Placed in water, it slowly swells. The "pain biscuité" of the French army is bread dried by heat (see Bread).

*Dried Potatoes* are sold in two forms—slices and granulated. In either case the potato is easily cooked, and is very palatable. It should be soaked in cold water first for some time, then slowly boiled, or, what is much better, steamed. The directions for cooking Edward's preserved potato (which is granulated) are: "To three quarters of a pound add about one quart of boiling water, stirring it at the same time; cover it closely; the basin or vessel used should be kept hot; let it stand for ten minutes; then well mash, adding butter, salt, &c., at discretion." It is stated to be equal to six times its bulk of the fresh vegetable, but this is hardly borne out by analysis: four times is as high as it would be safe to allow. Indeed both my own and Professor Attfield's analyses (see Report of Committee on Scurvy, 1877) show that a ℔ of preserved potato contains the solid matter of only 3½ ℔ of ordinary fresh potatoes. (F. de C.)

*Dried Vegetables* (*other than Potatoes*).—Dried and compressed vegetables of all kinds (peas, cauliflowers, carrots, &c.) are now prepared, especially by Messrs Masson & Challot, so perfectly that, if properly cooked, they furnish a dish almost equal to fresh vegetables. Professor Attfield (see Report of Committee on Scurvy) found that dried compressed cabbage contained the solids of *seven* times its weight of fresh cabbage, whilst the mixed vegetables contained *five and a half* times the solids of the fresh vegetables. They must be cooked very slowly. If there is any disagreeable taste from commencing putrefaction, which is very rare, a little chloride of lime removes it at once. Potassium permanganate can be also used for this purpose.

As anti-scorbutics they are said to be inferior to the fresh vegetable (experience of American war), but are still much better than nothing.*

*Dried Milk.*—Preserved milk is sold in a liquid form (see Milk), but is also sold as a powder. Desiccated milk is now very well prepared; I examined a sample of Fadeuille's desiccated milk; the bottle contained 1502 grains, consisting of—

| | |
|---|---|
| Casein, | 524·588 |
| Fat, | 330·442 |
| Lactin, | 492·265 |
| Salts, | 73·890 |

and intended to be mixed with a quart of water. When so mixed it had a specific gravity of 1026; a little sugar had probably been added. Cream to the extent of $\frac{3\cdot5}{100}$ths rose to the surface. The milk turned acid in twenty-four hours.

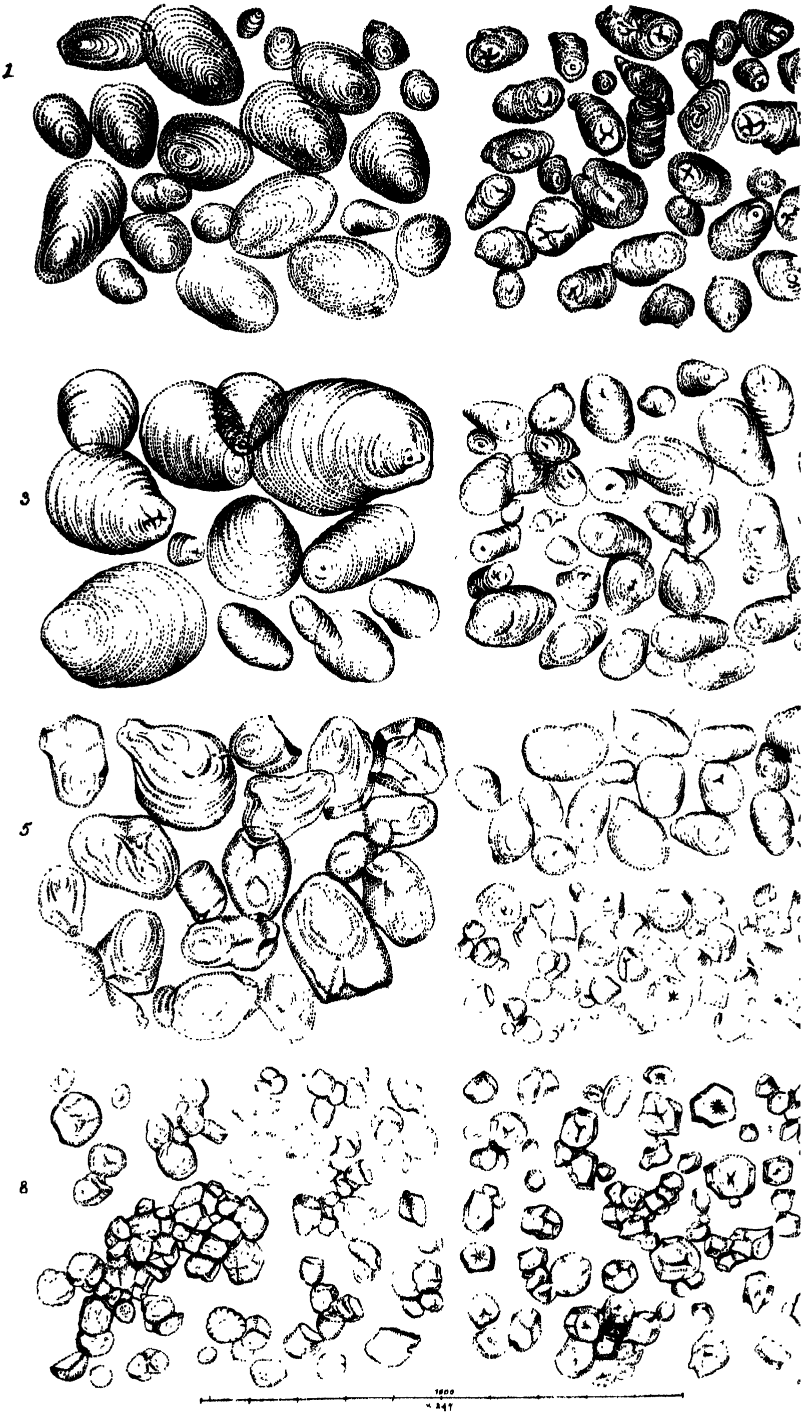
*Concentrated Milk.*—Milk is evaporated at low steam heat to the consistence of a thick syrup, and white sugar is added. I have examined four kinds, three of these being very similar, the fourth more watery, but of less cost. There was no impurity, and the casein, fat, and salts were in good proportion. The percentage of water was 20, 21·8, and 19·2 in the three concentrated milks, and 42·15 in the watery. After opening the tins all the samples remained good for over a month.

*Dried Eggs.*—The yolk is not easily kept after drying, but the white can be so; it is cut into thin scales, and forty-four eggs make about 1 ℔. The yolk and white are also mixed with flour, ground rice, &c., and are then dried.

---

* Professor Attfield (*loc. cit.*) considers that in the compressed vegetables some, at least, of the juice is lost in the preparation, probably by pressure.

Fig 1



1 Potato Starch
2 Bermuda Arrowroot
4. St Vincent Arrowroot
5. Sago of Commerce
7 Rio Arrowroot
8. Tapioca

# CHAPTER VII.

# BEVERAGES AND CONDIMENTS.

## SECTION I.

## ALCOHOLIC BEVERAGES.

Although it is convenient to place all the beverages which contain Alcohol under one heading, they yet differ materially in composition and effects.

### Sub-Section I.—Beer.

*Composition.*—The law formerly allowed only malt and hops to be used in brewing,[*] but since the repeal of the hop duties various bitter substances are used. Beer ought to consist of malt and hop extracts only,—of alcohol, formed by fermentation, and of salts added in the water, or present in the malt and hops.

The specific gravity varies from 1006 to 1030, or even more, in the thick German beers; the average in English beers and porters is from 1010 to 1014. The percentage of malt (dextrin, cellulose, sugar) is from 4 to 15 per cent. in ale, and from 4 to 9 per cent in porter. It is least in the bitter, and highest in the sweet ales. The hop extract (lupulite and resin) is in much smaller amount. The alcohol varies from 1 to 10 per cent. in volume. The free acidity which arises from lactic, acetic, gallic, and malic acids, ranges (if reckoned as dry acetic acid) from 15 to 40 grains per pint.[†] The sugar has a great tendency to form glucinic acid ($C_{12}H_{18}O_9$). There is a small quantity of albuminous matter in most beers, but not averaging more than ·5 per cent. The salts average ·1 to ·2 per cent., and consist of alkaline chlorides, and phosphates, and some earthy phosphates. There is a small amount of ammoniacal salt. The dark beers, or porters, contain caramel and assamar. Free carbonic acid is always more or less present; the average is ·1 to ·2 parts by weight per cent., or about 1¾ cubic inch per ounce. Volatile and essential oils are also present.

Adopting mean numbers, 1 pint (20 ounces) of beer will contain :—

| | |
|---|---|
| Alcohol, . . . . . . . | 1 ounce. |
| Extractives, dextrin, sugar, . . . | 1·2 „ (524 grains). |
| Free acid, . . . . . . . | 25 grains. |
| Salts, . . . . . . . | 13 grains. |

*Physiological Action.*—The action on tissue metamorphosis, as far as is known, is supposed to be one of lessened excretion; the urea and pulmonary carbonic acid being both decreased. If this be the case, it is not owing to the alcohol, at least in moderate dietetic doses, but to some of the other ingredients; but the experiments require repetition.[*] On the nervous system the action is probably the same as that of alcohol. The peculiar exhausting or depressing action of beer taken in large amount has been ascribed by Ranke[†] to the large amount of potash salts, but probably the other constituents (especially the hop) are also concerned.

---

[*] In the Licensing Act (1872), clause 19 contains penalties for using any deleterious substance for mixing with liquors sold by persons having licences under the Act, and in the first schedule to the Act is a list of deleterious ingredients, viz. :—"Cocculus indicus, chloride of sodium (otherwise common salt), copperas, opium, Indian hemp, strychnine, tobacco, darnel seed, extract of logwood, salts of zinc or lead, alum, and any other extract or compound of any of the above ingredients." Several articles, which are supposed to be used as adulterants, are omitted from this list.

[†] Reckoned as glacial acetic acid, these numbers would be slightly increased.

When beer is taken in daily excess, it produces gradually a state of fulness and plethora of the system, which probably arises from a continual, though slight interference with elimination, both of fat and nitrogenous tissues. When this reaches a certain point, appetite lessens, and the formative power of the body is impaired. The imperfect oxidation leads to excess of partially oxidised products, such as oxalic and uric acids. Hence many of the anomalous affections, classed as gouty and bilious disorders, which are evidently connected with defects in the regressive metamorphosis.

The question, what is excess? is not easy to answer, and will depend both on the composition of the beer, and on the habits of life of those who take it, but judging from the amount of alcohol which is allowable, from one pint to two pints, according to the strength of the beer, is a sufficient amount for a healthy man.

### EXAMINATION OF BEER.

This is directed to ascertain—1. Quality; 2. Adulterations.

#### 1. *Quality.*

1. *Physical Characters*—The beer should be transparent, not turbid. Turbidity arises from imperfect brewing or clarifying, or from commencing changes. If the latter, the acidity will probably be found to be increased. The amount of carbonic acid disengaged should neither be excessive nor deficient.

The taste should be pleasant. If bitter, the bitterness should not be persistent. It should not taste too acid.

Smell gives no indication till the changes have gone to some extent.

If there is any turbidity, there will be found on microscopic examination abundance of yeast cells and amorphous deposit.

2. *Determine Specific Gravity.*—If this is done after the alcohol is driven off (see Determination of Alcohol), an approximate conclusion can be formed of the amount of solids by dividing by 4 the excess of the specific gravity over 1000. The more malt extract, the greater is the *body* of the beer.

| Specific Gravity after loss of Alcohol. | Per cent. of Extract. | Specific Gravity after loss of Alcohol. | Per cent. of Extract. |
|---|---|---|---|
| 1004 | 1 | 1024 | 6 |
| 1008 | 2 | 1028·1 | 7 |
| 1012 | 3 | 1032·2 | 8 |
| 1016 | 4 | 1036·3 | 9 |
| 1020 | 5 | 1040·4 | 10 |

3. *Determine Acidity.*—This is a very important matter, as the increase of acidity is an early effect when beer is undergoing changes.

The acidity of beer consists of two kinds.

*Volatile Acids.*—viz., Acetic and carbonic.

*Non-Volatile Acids.*—viz., Lactic, gallic or tannic, malic, and sulphuric, if it has been added as an adulteration.

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[*] Binz (Journal of Anatomy and Physiology, May 1874) states that alcohol diminishes both the pulmonary carbonic acid and urea.

[†] Phys. des Menschen, 1868, p. 139.

To determine acidity of beer and all other liquids, the easiest plan is to prepare an alkaline solution of known strength.

### *Standard Alkaline Solution.*

A standard acid is first made, and crystallised oxalic acid ($C_2H_2O_4 + 2OH_2$) (equivalent 126) is now usually employed.

One-twentieth of an equivalent (6·3 grammes) is taken and dissolved in 1 litre of water. 1 C.C. of this solution contains therefore ·0063 grammes of crystallised oxalic acid, and is exactly equal, of course, to an equivalent proportion of any other acid.

A solution of liquor sodæ, or potassæ if soda cannot be obtained, is now taken and graduated with the acid solution; so that 1 C.C. of oxalic acid solution shall exactly neutralise 1 C.C. of the alkaline solution. Then 1 C.C. of the alkaline solution will be equal to ·0063 grammes of oxalic acid, or to an equivalent proportion of any other acid, as shown in the table.

| | | | |
|---|---|---|---|
| 1 C.C. alkaline solution equals | ·0063 | grammes | of crystallised oxalic acid ($C_2H_2O_4 + 2OH_2$). |
| ,, | ·0051 | ,, | acetic anhydride or anhydrous acetic acid ($C_4H_6O_3$). |
| ,, | ·0060 | ,, | glacial acetic acid ($C_2H_4O_2$). |
| ,, | ·0064 | ,, | citric acid ($C_6H_8O_7$).* |
| ,, | ·0075 | ,, | tartaric acid ($C_4H_6O_6$).* |
| ,, | ·0090 | ,, | lactic acid ($C_3H_6O_3$). |
| ,, | ·0040 | ,, | sulphuric anhydride or sulphuric trioxide ($SO_3$). |
| ,, | ·0049 | ,, | sulphuric acid ($SO_4H_2$)† |

In preparing the alkaline solution, dilute the common liquor potassæ of the pharmacopœia (if caustic soda cannot be had) with about 7 or 8 parts of water; put a portion into the burette, and add it to 10 C.C. of the standard acid, coloured with litmus or cochineal. It will be found that about 8 or 9 C.C. of the liquor potassæ will neutralise the 10 C.C. of acid; read off the amount of alkaline solution used, measure the remaining portion, and calculate by rule of three how much water must be added to dilute it, so that 10 C.C. shall be required to neutralise 10 C.C. of the acid.

*Example.*—10 C.C. of acid required 8·7 C.C. of alkaline solution, and the remainder of the alkaline solution measured 160 C.C.

$$8{\cdot}7 : 10 : : 160 : x$$
$$x = 183{\cdot}9.$$

Thus (183·9 − 160 =) 23·9 C.C. of water must be added to the 160 C.C., to dilute it to the proper strength. Add then this amount of water, and test it once more to see that there is no mistake. The alkaline solution does not keep well, and must be re-tested, if a long time passes without its being used.

Having prepared the alkaline solution, take a measured quantity of beer (say 10 C.C.), and drop in the alkaline solution from the burette, till exact neutrality is reached. Then read off the number of C.C. of alkaline solution used; multiply by the co-efficient of glacial acetic acid, and the result will be the amount of total acidity in the quantity of beer operated on, as expressed in glacial acetic acid (the symbols being always used in the report). By shifting the decimal point two places to the right, the amount per litre is given. To bring grammes per litre into grains per pint multiply by 70, and divide by 20; or, what is the same thing, multiply at once the number of centimetres of alkaline solution used by 5·25. If an ounce has been taken instead of 10 C.C., multiply the C.C. of alkaline solution by 1·85 to bring the amount into grains per pint.

---

* Citric acid is tribasic and tartaric acid bibasic, hence their relative neutralising quantities are respectively one-third and one-half of their equivalents.

† In stating the result of the inquiry, the composition of the acids should always be given, by adding the symbols, otherwise error may arise. If the symbols are given, no mistake is possible. It must be remembered that the atomic weights are those of the unitary system. With regard to litmus, it ought to be very good and neutral. The best way of making it is to make first a concentrated watery solution, then to add dilute sulphuric acid to slight acid reaction, boil, and then add liq. baryta to very slight alkaline reaction; destroy the alkaline reaction by passing through two or three bubbles of carbonic acid. Boil, filter, and add one-tenth part of alcohol. Cochineal is probably more convenient, as it gives a sharper reaction: for its preparation see page 81.

If the alkaline solution cannot be made, dried carbonate of soda must be used; weigh 53 grains, and dissolve in 1000 C.C. of distilled water; 1 C.C. = ·053 grains, and this is equivalent to ·063 grains of crystallised oxalic acid. If there is no burette, then weigh 100 grains of carbonate of soda; add portions gradually to the beer, and when the beer is neutralised, weigh the carbonate of soda remaining. Then calculate by rule of three.

As 53 is to the equivalent of the acid sought; so is the amount of carbonate of soda used to $x$; $x$ = amount of acid in the quantity of beer operated upon.

The total acidity can be divided into fixed and volatile by evaporation. While the total acidity is being determined, evaporate another measured quantity of beer to one-third, then dilute with water, and determine the acidity. The acetic and carbonic acids being volatile are driven off, and lactic and other acids remain. Deduct the amount of alkaline solution used in this second process from the total amount used, and this will give the amounts used for the volatile and fixed acidities respectively; express one in terms of acetic, the other of lactic acid. Short factor for lactic acid = 7·875. The fixed acidity is greater than the volatile in almost all beers, and sometimes five or six times as much.

Generally speaking the determination of total acidity of beer given in books is too great. I have seldom found it to be more than 30 grains per pint, and often less; sometimes not more than 14 or 15 grains. In 31 kinds of porter and stout recorded in the *British Medical Journal* (June 1870), the acidity per pint varied from 25·22 grains (the highest) to 14·14 grains (the lowest amount). In 23 kinds of ale, the highest and the lowest amounts per pint were 35·39 and 7·97 grains.

4. *Determine Amount of Alcohol.*—There are various ways of doing this, but one of the two following will be sufficient.

Measure a certain quantity, say one pint of beer, and take the specific gravity at 60° or 68° Fahr.* 1*st*, Put into a retort and distil at least two-thirds. Take the distillate, dilute to original volume with distilled water, determine the specific gravity at 60° or 68° by a proper instrument, and then refer to the annexed table of specific gravities—opposite the found specific gravity the percentage of alcohol is given in volume (not in weight).

2*d*, Then, to check this, a plan recommended by Mulder may be used. Take the residue of the beer in the retort, dilute with water to the original volume, and take the specific gravity at 60° or 68°.

Then deduct the specific gravity before the evaporation from the specific gravity after it, take the difference, and deduct this from 1000 (the specific gravity of water), and look in the table of specific gravities for the number thus obtained; opposite will be found the percentage of alcohol.* The results of these two methods should be identical.

---

* Hassall recommends previous removal of $CO_2$, by shaking up in a corked bottle for 10 minutes, opening the bottle from time to time, and sucking air through it with a tube. This is more necessary with bottled than draught beer.

If there is no retort, this second plan may be used with a common evaporating dish, the alcohol being suffered to escape. A common urinometer (tested for correctness in the first place by immersion in distilled water at 62° Fahr.) may be employed for determining the specific gravity. The plan is very useful for medical officers; it requires nothing but a urinometer and evaporating dish.†

*Alcohol (Volume) according to Specific Gravity.*

| 100 parts. | | Specific Gravity. | | 100 parts. | | Specific Gravity. | |
|---|---|---|---|---|---|---|---|
| Alcohol. | Water. | At 68°. | At 60°. | Alcohol. | Water. | At 68°. | At 60°. |
| 50 | 50 | 0·914 | 0·917 | 24 | 76 | 0·966 | 0·968 |
| 49 | 51 | 0·917 | 0·920 | 23 | 77 | 9·968 | 0·970 |
| 48 | 52 | 0·919 | 0·922 | 22 | 78 | 0·970 | 0·972 |
| 47 | 53 | 0·921 | 0·924 | 21 | 79 | 0·971 | 0·973 |
| 46 | 54 | 0·923 | 0·926 | 20 | 80 | 0·973 | 0·974 |
| 45 | 55 | 0·925 | 0·928 | 19 | 81 | 0·974 | 0·975 |
| 44 | 56 | 0·927 | 0·930 | 18 | 82 | 0·976 | 0·977 |
| 43 | 57 | 0·930 | 0·933 | 17 | 83 | 0·977 | 0·978 |
| 42 | 58 | 0·932 | 0·935 | 16 | 84 | 0·978 | 0·979 |
| 41 | 59 | 0·934 | 0·937 | 15 | 85 | 0·980 | 0·981 |
| 40 | 60 | 0·936 | 0·939 | 14 | 86 | 0·981 | 0·982 |
| 39 | 61 | 0·938 | 0·941 | 13 | 87 | 0·983 | 0·984 |
| 38 | 62 | 0·940 | 0·943 | 12 | 88 | 0·985 | 0·986 |
| 37 | 63 | 0·942 | 0·945 | 11 | 89 | 0·986 | 0·987 |
| 36 | 64 | 0·944 | 0·947 | 10 | 90 | 0·987 | 0·988 |
| 35 | 65 | 0·946 | 0·949 | 9 | 91 | 0·988 | 0·989 |
| 34 | 66 | 0·948 | 0·951 | 8 | 92 | 0·989 | 0·990 |
| 33 | 67 | 0·950 | 0·953 | 7 | 93 | 0·990 | 0·991 |
| 32 | 68 | 0·952 | 0·955 | 6 | 94 | 0·992 | 0·992 |
| 31 | 69 | 0·954 | 0·957 | 5 | 95 | 0·994 | 0·994 |
| 30 | 70 | 0·956 | 0·958 | 4 | 96 | 0·995 | 0·995 |
| 29 | 71 | 0·957 | 0·960 | 3 | 97 | 0·997 | 0·997 |
| 28 | 72 | 0·959 | 0·962 | 2 | 98 | 0·998 | 0·998 |
| 27 | 73 | 0·961 | 0·963 | 1 | 99 | 0·999 | 0·999 |
| 26 | 74 | 0·963 | 0·965 | 0 | 100 | 1·000 | 1·000 |
| 25 | 75 | 0·965 | 0·967 | | | | |

Alcohol is sometimes stated by weight in volume. The following table shows tolerably accurately the relation between the two and the relative amount of proof spirit, so that a little calculation will reduce one table into another if desired. In other words, if the percentage of alcohol in volume be multiplied by ·8, the weight of the alcohol is given per cent. If the percentage of alcohol in weight is multiplied by 1·25, the volume is given. If the percentage volume of alcohol be multiplied by 1·76, the amount of proof-spirit is given.

---

* It may be puzzling at first to see how this plan gives the result; but it is simple enough. As alcohol is lighter than water, the evaporation raises the specific gravity of the beer in proportion to the loss of alcohol, and the gain of the beer in specific gravity from the evaporation is exactly equal to the depression in specific gravity which that amount of alcohol would cause if added to pure water equal in bulk to the beer operated upon.

† Some difficulty, however, occasionally arises, if the heat in evaporation is carried too far, particularly if the extract on the sides of the dish be charred and thus rendered insoluble, In such a case the only way is, after making up to the original bulk with distilled water, to shake it well up and pour it into a specific gravity bottle and weigh. With care, however, and slow evaporation, this difficulty may be avoided.

| Per cent. in Volume. | Per cent. in Weight. | Proof Spirit. |
|---|---|---|
| 1 | ·8 | 1·76 |
| 2 | 1·6 | 3·54 |
| 3 | 2·4 | 5·35 |
| 4 | 3·2 | 7·09 |
| 5 | 4·0 | 8·80 |
| 6 | 4·8 | 10·56 |
| 7 | 5·6 | 12·32 |
| 8 | 6·4 | 14·00 |
| 9 | 7·2 | 15·76 |
| 10 | 8·0 | 17·60 |

5. The solids can be determined by evaporation, and the ash obtained by incineration ; but medical officers will seldom have occasion to do this. The specific gravity of the de-alcoholised beer gives a sufficient approximation.

6. Evaporate the beer to a syrupy consistence; it should be a pleasant bitter.

The points, then, to be determined in judging of quality are—1. Taste; 2. Appearance; 3. Specific gravity of de-alcoholised beer, from which we find the per cent. of extract; 4. Acidity; 5. Amount of alcohol; 6. Taste of syrupy extract.

### 2. *Adulterations of Beer.*[*]

1. *Water.*—Probably the most frequent adulteration; detected by taste ; determining amount of alcohol and specific gravity of the beer free from alcohol.

2. *Alcohol.*—Seldom added; the quantity of alcohol is large in proportion to the amount of extract, as determined by the specific gravity after separation of the alcohol.

3. *Sodium* or *Calcium Carbonate in order to lessen Acidity.*—Neither adulteration can be detected without a chemical examination. Evaporate beer to a thick extract, then put in a retort, acidulate with sulphuric acid, and distil; if calcium or sodium acetate be present, acetic acid in large quantity will pass over. The extract always contains some acetate, but only in small quantity.

*Lime.*—Evaporate to dryness another portion of beer, incinerate, dissolve in weak acetic acid, and precipitate by ammonium oxalate. In unadulterated beer the precipitate is moderate only.

*Excess of soda*, for some always exists in beer, is detected with much greater difficulty, and it will be well not to attempt this. Mulder states that the presence of too great a quantity of lactates may be determined by boiling the beer with zinc carbonate, when lactate of zinc deposits.[†]

4. *Sodium Chloride.*—This is hardly an adulteration, unless a very large quantity is added.[‡] Take a measured quantity of the beer; evaporate to dryness; incinerate; dissolve in water, and determine the chlorine by the standard solution of nitrate of silver. (See Analysis of Water.)

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[*] In his speech in the House of Lords (April 17, 1872, *Times'* report), Lord Kimberley stated that a common adulteration is as follows:—A certain amount of beer is drawn from the cask of 84 gallons, and then 6 lb of "foots" (a black coarse sugar), 1¼ gallon of "finings" (made from skins of soles and other fish), and 12 gallons of water are put in per cask. This beer is ready for sale in two hours, and must be drunk in two days or it goes bad. Salt and copperas are added by some, but the use of copperas is said not to be general. Ale and stout are not mixed with water, but "finings" are used. See page 277 for the list of deleterious articles scheduled in the Licensing Act.

[†] De la Bière (French edition), 1861, p. 258.

[‡] The Inland Revenue office allows 50 grains of sodium chloride per gallon.

5. *Ferrous Sulphate.*—If the beer be light-coloured, a mixture of potassium ferricyanide and ferrocyanide (Faraday's test) may be added at once, and will give a precipitate of Prussian blue; if the beer be very dark-coloured, it must be decolorised by adding solution of lead subacetate and filtering.

Or evaporate a portion of beer to dryness and incinerate; if any iron be present the ash is red; dissolve in weak nitric acid, and test with potassium ferrocyanide. Two grains of ferrous sulphate to nine gallons of water give a red ash (Hassall). The ash of genuine porter is always white, or greyish white (Hassall).

6. *Sulphuric acid* is added to clarify beer, and to give it the hard flavour of age. If the beer be pale, add a few drops of hydrochloric acid, and test with barium chloride. A *very dense* precipitate may show that sulphuric acid has been added, but it must be remembered that the water used in brewing may contain large quantities of sulphates. (The Burton spring water is rich in calcium sulphate.) If there be a *large* precipitate, then determine the acidity of the beer before and after evaporation; if the amount of fixed acid be found to be *very* large, there will be no doubt that sulphuric acid has been added; or precipitate with baryta and weigh. (See Water.)

Mulder recommends that the extract of the beer be heated, and the sulphurous acid gas which is disengaged led into chlorine water; sulphuric acid will be found in the chlorine water, and may be tested for as usual.

7. *Alum.*—Evaporate to dryness; incinerate, and proceed exactly as in the analysis of alum in bread. The substance added to give "head" to beer is a mixture of alum, salt, and ferrous sulphate.

8. *Burnt Sugar—Essentia bina—Foots.*—Evaporate beer to extract; dissolve in alcohol; evaporate again to extract, and taste. According to Pappenheim, these substances prevent the regressive metamorphosis of the tissues, and thus injure health. Burnt sugar is added to porter to give colour, and the addition is not illegal.

9. *Capsicum—Peppers—Grains of Paradise.*—Evaporate to dryness carefully; dissolve in alcohol; filter; evaporate very carefully to dryness, and taste if there is any pungency. In fourteen out of twenty samples of illicit beer, Mr Phillips found that grains of paradise had been added. It is said that the oils of pimenta, zedoary, and ginger are sometimes added.

10. *Aloes.*—The taste alone is not reliable. Dr Koehler* proposes to evaporate the beer. Dissolve the residue in nitric acid, when a yellowish-red liquid is obtained, which takes a deep blood-red colour when treated with liq. potassæ and glucose, or with liq. potassæ and either cyanide of potassium or sulphide of ammonium, if aloe-resin is present. The nitric acid solution is not decolorised by stannous chloride; if hops only have been used, it is decolorised.

11. *Colocynth.*—The residue of evaporated beer, heated with nitric acid, yields a yellow solution; with concentrated sulphuric acid, an intense red solution; and a cherry-red colour is given with Froehde's test (molybdate of sodium dissolved in sulphuric acid).†

12. *Colchicin.*—A case is recorded in the *Med. Times and Gazette* (May 16, 1874, p. 29) by Dr Böttern of Faaborg, in Norway, where colchicin was detected in some English beer, and caused symptoms of poisoning (vomiting, diarrhœa, burning pain in the head, stomach, &c.)

13. *Santonin.*—Evaporate beer to extract; treat with alcohol, filter, evaporate, and prepare the santonin as usual by boiling with lime, and precipitating by an acid.

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* Schmidt's Jahrb., 1871, No. 10, p. 22.

† Koehler, *op. cit.*

14. *Cocculus indicus.*—It is not known whether much of this is now used. The witnesses examined some years ago (1856) by the Committee of the House of Commons (Scholefield's) all doubted it; a large quantity of *Cocculus indicus* is, however, annually imported, and no other use is known.* In two instances out of twenty specimens of adulterated beer, analysed in 1863 by Mr Phillips, *Cocculus indicus* was found in large quantities.

For the detection of Picrotoxine, Herapath recommends that the beer be first treated with lead acetate; filtered; excess of lead got rid of by sulphuretted hydrogen; fluid evaporated to a small bulk, and mixed with animal charcoal. The charcoal absorbs the picrotoxine; it is boiled in alcohol, and the alcohol is evaporated on slips of glass. The picrotoxine crystallises as plumose tufts of circular or oat-shaped crystals.

Dr Langley of Michigan† recommends acidulating the beer with hydrochloric acid and agitating with ether; the etherial solution yields on evaporation crystals of picrotoxine.

A plan devised by Depaire is considered by Koehler as one of the easiest and at the same time the best. Mix one litre of beer with finely powdered rock salt: resinous and extractive matters are thrown down. Shake the liquid with ether; an impure picrotoxine is obtained, which can be purified.

None of these processes will give more than $\frac{4}{10}$ths of the picrotoxine.

When the crystals of picrotoxine are obtained, test them as follows:—

(*a*) Rub the crystals with 3 or 4 parts of pure nitrate of potassium; add 1 or 2 drops of strong sulphuric acid, and then an excess of strong solution of soda or potash. A bright reddish-yellow colour is given, if picrotoxine be present (Langley).

(*b*) Dissolve the crystals in strong sulphuric acid; a yellow fluid is obtained. Stir it with a glass rod which has been dipped in a concentrated solution of potassium bichromate; a bluish violet colour is obtained (like a strychnine reaction), which changes soon into brown, brown green, and at last apple green.

(*c*) If a good deal of picrotoxine is obtained, dissolve it in water, and put a small fish in the water; the poisonous effects occur in a short time.

15. *Strychnine* or *Nux Vomica.*—This is a very uncommon adulteration, if it ever occur. Add animal charcoal to the beer; digest for twenty-fours hours; pour off beer; boil the charcoal in alcohol; filter; evaporate one-half; add a few drops of liquor potassæ and then ether; agitate; pour off ether, and evaporate to dryness; test for strychnine by the colour test (sulphuric acid and bichromate of potash, or peroxide of lead, or manganese, or potassium permanganate).‡

16. *Tobacco* is occasionally used; in twenty specimens of illicit beer examined in 1863, by Mr Phillips of the Inland Revenue department, tobacco was found in one.

17. *Picric (Trinitrophenic) Acid.*—Lassaigne recommends the addition of subacetate of lead and animal charcoal; if the beer has still a yellow colour, picric acid is present. But, as Mulder and Hassall observe, many beers destitute of picric acid remain yellow. Pohl advises to add white uncombed wool; if picric acid be present, it stains it. This is an uncertain test. H. Brunner extracts the picric acid from the wool with hot aqueous ammonia; concentrates to a small bulk, and tests with a drop of solution of cyanide of potassium. A red coloration of isopurpurate of potassium will be produced if there be 1 part of picric acid in 500,000 of water (Hassall).

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* It is said to be obtainable from wholesale druggists under the name of *multum*.

† Chemical News, Sept. 6, 1862.

‡ Other vegetable bitters are used, but their detection is difficult and uncertain. Mr Sorby recommends the spectroscope for detecting calumba root.

18. *Copper.*—Evaporate a portion of the beer to dryness; incinerate; dissolve in weak nitric acid; test for copper by the insertion of a clean knife; by addition of ammonia and of potassium ferrocyanide.

19. *Lead.*—Evaporate a considerable quantity of the beer to dryness; incinerate; dissolve in weak nitric acid, and test for lead as usual. (See Analysis of Water.)

## SUB-SECTION II.—WINES.*

### *Composition.*

The composition of wine is so various that it is difficult to give a summary. The following are the chief ingredients:—

1. *Alcohol.*—From 6 to 25 per cent., volume in volume, of anhydrous alcohol. It has been, however, stated that the fermentation of the grape, when properly done, cannot yield more than 17 per cent., and that any amount beyond this is added.† Some of the finest wines do not contain more than 6 to 10 per cent.

| | Per cent of Alcohol (Volume in volume). | | |
|---|---|---|---|
| Port (*analysed in England*), | 16·62‡ | to | 23·2 |
| Sherry (*analysed in England*), | 16 | „ | 25 |
| Madeira (*analysed in England*), | 16·7 | „ | 22 |
| Marsala (*analysed in England*), | 15 | „ | 25 |
| Bordeaux wines, red (mean of 90 determinations of different sorts: Chateau Lafite, Margaux, Larose, Barsac, St Emilion, St Estèphe, &c.), | 6·85 | „ | 13 |
| Bordeaux wines, white (mean of 27 determinations of sorts: Sauternes, Barsac, Bergerac, &c.), | 11 | „ | 18·7 |
| Rhone wines, red (Hermitage, Montpellier, Frontignan, &c.), | 8·7 | „ | 13·7 |
| Rousillon, | 11 | „ | 16 |
| Burgundy, red (Beaune, Macon), | 7·3 | „ | 14·5 |
| „ white (Chablis, Macon, Beaune), | 8·9 | „ | 12 |
| Pyrennean, | 9 | „ | 16 |
| Champagnes, | 5·8 | „ | 13 |
| Moselles, | 8 | „ | 13 |
| Rhine wines (Johannisberg, Hochheimer, Rüdesheimer, &c.), | 6·7 | „ | 16 |
| Hungarian wine, | 9·1 | „ | 15 |
| Italian, | 14 | „ | 19 |
| Syria, Corfu, Samos, Smyrna, Hebron, Lebanon, | 13 | „ | 18 |

So various is the amount of alcohol in wines from the same district, that a very general notion only can be obtained by tables, and a sample of the wine actually used must generally be analysed.

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* For a full account of wines, see the work by Thudichum and Dupré (Origin, Nature, and Use of Wine, 1872).

† Mulder (On Wine, p. 186) quotes Guijal to the effect that pure port never contains more than 12·75 per cent. of pure alcohol; but Mulder doubts this. Dr Gorman stated before the Parliamentary Committee that pure sherry never contains more than 12 per cent. of alcohol, and that 6 or 8 gallons of brandy are added to 108 gallons of sherry. Thudichum and Dupré (On Wine, p. 682), state that a natural wine may contain a minimum of 9, while the maximum limit is 16 per cent. (of weight in volume). They also state that a pipe of 115 gallons of port wine has never less than 3 gallons of brandy added to it, and the rich port wines have 13 to 15 gallons added. It would seem that the natural wines of Australia contain a larger quantity of alcohol in some instances than any European wine.

‡ Some port used in the Queen's establishment contained only 16·62, and the highest per centage was 18·8 (Hofmann). The sherry contained only 16 per cent., and the claret 6·85 to 7 per cent. The highest percentage found by Thudichum and Dupré in port wine was 19·2 per cent. of weight in volume=23·4 per cent. volume in volume.

To tell how much pure alcohol is taken in any definite quantity of wine, measure the wine in ounces, multiply it by the percentage of alcohol, and divide by 100.

*Example.*—Wine drank being 9 oz., and the percentage 13, then $\frac{9 \times 13}{100}$ = 1·17 oz. of absolute alcohol.

The amount of alcohol can be determined by distillation or evaporation, as given in the section on Beer. Instruments, however, are required, which indicate a less specific gravity than pure water. If the medical officer has only a common urinometer, the only plan will be to dilute with an equal part of pure water at 60°, and then to add a little salt, so as to bring the specific gravity above that of water; then evaporate as usual. Take the difference of the specific gravities (before and after evaporation); deduct from 1000, and look in the table (p. 281) for the amount of alcohol in the diluted wine; by multiplying the result by 2, the percentage of alcohol in the undiluted wine is found. Sometimes, besides ethyl alcohol, small quantities of propyl, butyl, and amyl alcohols are found in wine. A little acet-aldehyde is present in some Greek wines (Thudichum and Dupré), but is not considered to indicate unsoundness.*

2. *Ethers.*—Œnanthic, citric, malic, tartaric, racemic, acetic, butyric, caprylic, caproic, pelargonic, and many others. Dr Dupré states that there are 25 or even more compound ethers in wine, and some of them are in very small quantities. The "bouquet" of wine is partly owing to the ethers (especially to the volatile)—partly, it is said, to extractive matters. Œnanthic ether is that which gives its characteristic odour to wine. Dr Dupré has given a very good plan of estimating the amount of the volatile and non-volatile ethers, but it is too delicate for medical officers.†

3. *Albuminous Matters—Extractive Colouring Matter.*—The quantity of albumen is not great; the extractives and colouring matter vary in amount. The colouring matter is derived from the skins; it is naturally greenish or blue, and is made violet and then red by the free acids of wine. The bluish tint of some Burgundy wines is owing, according to Mulder, to the very small amount of acetic acid which these wines contain. It is, according to Batilliat, composed of two matters—rosite and purpurite. With age changes occur in the extractive matters; some of it falls (apothema), especially in combination with tannic acid, and the wine becomes pale and less astringent.

4. *Sugar* exists in varying amounts, and in the form for the most part of fruit sugar. Sherry generally contains sugar, but not always; it averages 8 grains per ounce,‡ and appears to be highest in the brown sherries, and least in Amontillado and Mazanilla. In Madeira it varies from 6 to 66 grains per ounce; in Marsala a little less; in port, from 16 to 34 grains per ounce, being apparently greatest in the finest wine. In champagne it amounts to from 6 to 28 grains, the average being about 24 grains. In the clarets, Burgundy, Rhine, and Moselle wines, it is absent, or in small amount.

In determining the sugar, if the copper solution (p. 264) be used, the colouring matter is acted on by the alkali of the copper solution, and interferes with the appreciation of the change of tint, and must be got rid of by acetate of lead, animal charcoal, boiling, and filtering. If any substance exists which is still turned green by the alkali of the copper solution, the wine must be neutralised, evaporated to dryness, and the sugar dissolved. As a rule, the copper solution employed directly with wine gives ½ per cent. too much sugar (Fehling), and a correction to this amount should be made.*

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* If it is present in white wines (such as Sauternes) it is a certain sign of unsoundness.

† Chem. Journal, Nov. 1867, and "Origin, Nature, and Use of Wine."

‡ Bence Jones in "Mulder on Wine," p. 386.

5. *Fat.*—A small amount exists in some wine.

6. *Free Acids.*—Wine is acid from free acids and from acid salts, as the bitartrate of potash. The principal acids are racemic, tartaric, acetic, malic, tannic (in small quantities), glucic, succinic, lactic (?), carbonic, and fatty acids, such as formic, butyric, or propionic. Some acids are volatile besides the acetic, but it does not seem quite certain what they are. The tannic acid is derived from the skins ; it is in greatest amount in new port wines ; it is trifling in Madeira and the Rhine wines ; it is present in all white and most red-fruit wines, except champagne. The tannic acid on keeping precipitates with some extractive and colouring matter (apothema of tannic acid).

7. *Salts.*—The salts consist of bitartrate of potassium, tartrates of calcium and sodium, sulphate of potassium, a little phosphate of lime and magnesia, chloride of sodium, and iron. The magnesia is in larger amount than the lime, and exists sometimes as malate and acetate. A little manganese and copper have been sometimes found. In Rhine wine a little ammonia is found (Mulder). The total amount of salts is ·1 to ·3 per cent.—*i.e.*, about 9 to 26 grains per pint, or ½ to 1½ grain per ounce. The salts can only be detected by evaporation and ignition.

8. The total solids in wine vary from 3 to 14 per cent., or in some of the rich liqueur-like wines to more. The specific gravity depends upon the amount of alcohol and of solids, and varies from ·973 to 1·002 or more. An approximate notion can be formed of the total solids by taking the specific gravity, after driving off the alcohol by evaporation, and then replacing the water (see Beer, p. 278).

## EXAMINATION OF WINE.

The quality of wine can be best determined by noting the colour, transparency, and taste, and then determining the following points :—

(1.) The amount of solids as given by the specific gravity after the elimination of the alcohol. In the best clarets, before the loss of alcohol, the specific gravity is very nearly that of water. In some claret used in the Queen's establishment, and analysed by Dr Hofmann, the specific gravity was ·9995?. In other clarets it is as low as ·995. The low specific gravity shows that alcohol has been added, or that the solids are in small amount.

(2.) The amount of alcohol; a very small amount may show the addition of water ; a large amount the addition of spirits.

(3.) The amount of free acidity. This is an important point, as it seems clear that some persons (especially the sick) do not readily digest a large amount of acid and acid salts.

The amount is determined by the alkaline solution, as described in the section on Beer, or if this is not procurable, the dried carbonate of sodium can be used. The free acidity is generally reckoned as crystallised tartaric acid ($C_4H_6O_6$). There is both fixed and volatile acidity; the relative amount of the two is difficult to determine satisfactorily, as some acid may be formed on distillation. The distillation should be conducted at a low temperature, so as not to decompose the fixed compound ethers. The volatile acidity is reckoned as glacial acetic, the fixed as tartaric acid.

The amount of free acidity varies greatly even in the same kind of wines; the least acid wines are sherry, port, champagne, the best claret and Madeira; the more acid wines are Burgundy, Rhine wine, Moselle (Bence Jones). The amount of free acid in good clarets is equal to 2 or 4 grains of tartaric acid per ounce ; in common clarets and in Beaujolais, it may be 4 to 6 grains, and in some extremely acid wines it may be even more than this. In the best champagnes it is 2 to 3 grains usually ; but it has been known to reach in excellent champagne 1·12 per cent., or 4·8 grains per ounce.[*] In port it averages 2 to 2½ grains, but may reach 4 grains ; in sherry 1½ to 2¼ grains ; in the Rhine wines, 3½ to 4 or 6 grains. Thudichum and Dupré state that in good sound wine the amount of free acidity ranges from ·3 to ·7 per cent., or from 1·3 to 3 grains per ounce.

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* The addition of extraneous sugar to wine may be detected by the use of the saccharometer along with Fehling's solution.

The taste of wine does not depend entirely on, but yet is very greatly influenced by the degree of acidity. Mr Griffin[†] states that good-tasted wine contains from 1·87 to 2·8 grains of crystallised tartaric acid per ounce ; that if it contains less than 1·87 grains it tastes flat ; that if more than 3 grains per ounce, the wine is too acid to be agreeable ; if more than 4·37 grains per ounce (1 per cent.), it is too acid to be drunk. These numbers are rather lower than I should have supposed.[‡]

(4.) The amount of sugar. The best modes of determining this have been already noticed.

(5.) It may be sometimes useful to determine the amount and kind of ethers by fractional distillation.

Excessive acidity of wine can be corrected by adding neutral tartrate of potash. Milk is also often used. The addition of the carbonated alkalies, or of chalk, alters the bouquet of the wine. When wine becomes stringy, in which case acetic and lactic acids are formed, it may be improved by adding a little tea ; about 1 ounce of tea boiled in 2 quarts of water should be added to about 40 gallons of wine. Bitter wine is treated with hard water or sulphur ; bad smelling wine with charcoal ; too astringent wine with gelatine ; wine which tastes of the cask with olive oil.[§]

### *Adulterations of Wine.*

1. *Water.*—Known by taste ; amount of alcohol ; specific gravity after elimination of alcohol.

2. *Distilled Spirits.*—Known by determining the amount of alcohol ; the normal percentage of the particular kind of wine being known. By fractional distillations the peculiar-smelling fusel oils may be obtained ; or merely rubbing some of the wine on the hand, and letting it evaporate, may enable the smell of these ethers to be perceived.

3. *Artificial Colouring Matters.*—The following are the chief colouring matters, as stated by Thudichum and Dupré. Logwood is the great colouring material, and also blackberries, elderberries, and bilberries. There are no good methods of recognising these substances ; salts of lead, ammonia, and ammonium sulphide, alum, and potassium or ammonium carbonate, and salts of tin have been used as re-agents. The most useful test appears to be this : add to the wine about ¼th volume of strong solution of alum ; stir well, and then add about an equal quantity of strong solution of ammonium carbonate ;

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[*] This was the case in some champagne examined by Dr Hofmann.

[†] Report on Cheap Wine, by R. Druitt, M.D., p. 178.

[‡] From 13 analyses of sound ordinary port, I found the mean acidity to be 1·97 per ounce ; in some samples of sherry, 1·90 ; marsala, 1·5 ; light claret, 3·1 ; in a rather sour claret, 4·0 ; in a sample of Montilla, a fine wine, but too acid, 3·15. (F. de C.)

[§] Wine is subject to several diseases, which, according to Pasteur, depend on different kinds of ferments (see Review on Hygiene in Army Medical Department Report, vol. vii. p. 340). By heating the wine to about 125° to 131° Fahr. these "mycoderms" are killed, and the wine undergoes no further change.

the natural colouring matter of the wine when thrown down in this way has a greenish or dirty bluish-green colour, but there is no tinge of red; logwood and several other abnormal colours have a distinct red or purplish tint.*

4. *Lime Salts.*—The so-called "plâtrage" of wines consists in the addition of 1½ ℔ to 7 ℔ of a mixture of sulphate of lime (80 parts), carbonate of lime (12), quicklime and sulphide and chloride of calcium (8 parts) to 1 hectolitre of wine. Sulphate of lime dissolves in large proportion, and then interchanges with the chloride of potassium, and chloride of calcium and sulphate of potassium are formed. The chalk forms acetate and tartrate of lime. The proportion of lime salts is then very large. The only precise way of detecting this adulteration is by evaporating to dryness, incinerating, and determining the amount of lime. But the following method is shorter, and will generally answer. The natural lime salts of wine are tartrate and sulphate; when lime is added an acetate of lime is formed. Evaporate the wine to $\frac{1}{10}$th; add twice the bulk of strong alcohol; the acetate of lime is dissolved, but not the sulphate or tartrate; filter and test with oxalate of ammonium; if a large precipitate occur, lime has probably been added.

5. *Tannin* may be detected either by chloride of iron or by adding gelatine. But as tannin exists naturally in most of the red wines (Port, Beaune, Roussillon, Hermitage, &c.), the question becomes often one of quantity. The amount of tannin can be estimated by drying the tannogelatine (100 grains contain 40 of tannin).

6. *Alum.*—This is detected precisely in the same manner as in bread. Evaporate a pint of the wine to dryness; incinerate, and then proceed as directed in BREAD.

7. *Lead.*—Evaporate to dryness, and incinerate; dissolve in dilute nitric acid, and test as directed under the head of WATER.

8. *Copper.*—Decolorise with animal charcoal, and test at once with ferrocyanide of potassium.

9. *Cider and Perry.*—Evaporate wine, and the peculiar smell of the liquids will be perceived.

Port wine, as sold in the market, is stated to be a mixture of true Port, Marsala, Bordeaux, and Cape wines with brandy. Inferior kinds are still more highly adulterated with logwood, elderberries, catechu, prune juice, and a little sandalwood and alum. Receipts are given in books for all sorts of imitation wines.

### SUB-SECTION III.—SPIRITS.

The Queen's Regulations for the Army (1868, sec. 1010), forbid the sale of spirits in canteens at home, but permit it in foreign stations at the option of the commanding officer.

Brandy contains, besides alcohol, œnanthic ether, acetic, butyric, and valerianic ethers. Tannin and colouring matter from the cask, or from caramel, are present. If sugar is present in any quantity, it must have been added. The inferior kinds of brandy, prepared from potatoes as well as grain, contain potato fusel-oil. Rum contains a good deal of butyric ether, to which the aroma is chiefly owing. Gin, besides containing the oil of juniper, is flavoured with various aromatic substances, as *Calamus aromaticus*, coriander, cardamoms, cinnamon, almond-cake, and orange-peel; Cayenne is often added.

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* Mulder speaks very doubtfully of all such tests; they seem, however, better than nothing. Probably the spectrum analysis will hereafter afford the best means of identification. On the colouring matter of wine, see Duclaux, Comptes Rendus de l'Académie des Sciences, T. lxxviii., No. 16, April 1874, p. 1159; also, Report on Hygiene, Army Med. Reports, vol. xv. p. 190.

Whisky often derives a peculiar flavour from the malt being dried over peat fires, or by the direct impregnation of peat smoke.[*]

### *Composition of Spirits.*

The following table gives the chief points of importance :—[†]

| Name. | Sp. gr. at 62° F. | Alcohol per cent. | Solids per cent. | Ash per cent. | Acidity per ounce, reckoned as tartaric acid. | Sugar per cent. |
|---|---|---|---|---|---|---|
| Brandy, . . | ·929–·934 | 50–60 | 1·2 | ·05 to ·2 | 1 grain | 0 or traces |
| Gin, . . . | ·930–·944 | 49–60 | ·2 | ·1 | 0·2 | 1 |
| Whisky, . . | ·915–·920 | 50–60 | ·6 | trace | 0·2 | 0 |
| Rum, . . . | ·974–·926 | 60–77 | 1 | ·1 | 0·5 | 0 |

## ALCOHOL AS AN ARTICLE OF DIET IN HEALTH.[‡]

In endeavouring to determine the dietetic value of alcoholic beverages, it is desirable to see, in the first place, what are the effects of their most important constituent, viz., alcohol.

Three sets of arguments have been used in discussing this question, drawn, namely, from—

1. The physiological action of alcohol.
2. Experience of its use or abuse.
3. Moral considerations.

To the last point I shall not further allude, for though I do not underrate the great weight of the argument drawn from the misery which the use of alcohol produces,—a misery so great that it may truly be said, that if alcohol were unknown, half the sin and a large part of the poverty and unhappiness in the world would disappear,—yet this part of the subject is so obvious that I do not wish to occupy space with it. To my mind, however, the arguments which are strongest for total abstinence are drawn from this class. Nor does any one entertain a moment's doubt that the effect of intemperance in any alcoholic beverage is to cause premature old age, to produce or predispose to numerous diseases, and to lessen the chance of living very greatly. The table

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[*] It may be worth while to give the names of some of the distilled spirits used in different parts of the world, as the army surgeon may meet with them in the course of service :—

| Nations by whom employed. | Name. | Obtained from. |
|---|---|---|
| Hindus, Malays, &c., | Arrack. | Rice or Areca-nut. |
| Greeks, Turks, &c., | Raki. | Rice. |
| Hindus, | Toddy. | Cocoa-nut. |
| „ (Mahrattas), | Bojah. | Eleusine Corocana. |
| „ (Sikkim), | Murwa. | „ „ |
| Chinese, | Samshoo. | Rice. |
| Japanese, | Sácie. | ... |
| Pacific Islanders, | Kawa. | Macropiper. |
| Mexicans, | Pulque. | Agave. |
| South Americans, | Chica. | Maize. |
| Tartars, | Koumiss. | Mares' milk. |
| Russians and Poles, | Vodki. | Potato. |
| Abyssinians, | Tallah. | Millet. |

[†] This table is chiefly taken from Bence Jones' Observations; Appendix to Mulder on Wine. p. 389; and from Hassall's Food and Adulteration, p. 645.

[‡] The subject of spirits in sickness is another point altogether. I believe they are often of great use, although, like every other strong medicine, they require to be given carefully. The fashionable plan of giving great quantities of strong spirits is happily dying out, and is being replaced by a more careful practice.

given below,* taken from Neison's "Vital Statistics," puts this in a strong light.

The physiological argument for the use or disuse of alcohol requires to be used with caution, as our knowledge of the action of pure alcohol (much more of the alcoholic beverages) is imperfect.

When taken into the stomach, alcohol is absorbed without alteration, or is

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Effects of intemperance, Neison's Statistics," p. 217, *et seq.* :—

*Ratio per cent. from the under-mentioned Causes, to Deaths from all Causes.*

| Cause of Death. | 1847. | Gotha Life Office. | Scottish Widows' Fund. | Intemperate Lives. |
|---|---|---|---|---|
| Head diseases, . . . . . | 9·710 | 15·176 | 20·720 | 27·10 |
| Digestive organs (especially those of the liver), . . . . . | 6·240 | 8·377 | 11·994 | 23·3 |
| Respiratory organs, . . . . | 33·150 | 27·843 | 23·676 | 22·98 |
| Total of above three classes, . | 49·100 | 51·396 | 56·390 | 73·38 |

It thus appears that the intemperate have a much greater mortality from head and digestive diseases than other classes.

In intemperate persons the mortality at 21–30 years of age is five times that of the temperate ; from 30–40 it is four times as great. It becomes gradually less.

| A Temperate person's chance of living is, | An Intemperate person's chance of living is, |
|---|---|
| At 20 = 44·2 years. | At 20 = 15·6 years. |
| „ 30 = 36·5 „ | „ 30 = 13·8 „ |
| „ 40 = 28·8 „ | „ 40 = 11·6 „ |
| „ 50 = 21·25 „ | „ 50 = 10·8 „ |
| „ 60 = 14·285 „ | „ 60 = 8·9 „ |

All these deductions appear to be drawn from observations on 357 persons with 6111·5 years of life. The facts connected with these persons are well authenticated, but the number is small.

The average duration of life after the commencement of the habits of intemperance is—

| | |
|---|---|
| Among mechanics, working and labouring men, . . . | 18 years. |
| „ traders, dealers, and merchants, . . . . . . | 17 „ |
| „ professional men and gentlemen, . . . . . . | 15 „ |
| „ females, . . . . . . . . . . . | 14 „ |

Those who are intemperate on spirits have a greater mortality than those intemperate on beer.

Those who are intemperate on spirits and beer have a slightly greater mortality than those intemperate on only spirits or beer, but the difference is immaterial.

| | Mortality per annum. |
|---|---|
| Spirit drinkers, . . . . . | 5·996 per cent. (nearly 60 per 1000). |
| Beer drinkers, . . . . . | 4·597 per cent. (nearly 46 per 1000). |
| Spirit and beer drinkers, . . . . | 6·194 per cent. (nearly 62 per 1000). |

Very striking evidence in favour of total abstinence, as contrasted with moderation, is given by the statistics of the United Kingdom Temperance and General Provident Institution. One section consists of abstainers, another of persons selected as not known to be intemperate. The claims for five years (1860–70), anticipated in the Temperance section were £100,446 ; but there were actually only claims for £72,676. In the general section, the anticipated claims were £196,352 ; and the actual claims were no less than £230,297. The much greater longevity of the abstainer is better seen by the amount of bonuses paid to each £1000 whole-life policy in the two sections for the same five years.

| Age at Entrance. | Premiums Paid. | | | Bonus added in Temperance Section. | | | Bonus added in General Section. | | |
|---|---|---|---|---|---|---|---|---|---|
| | £ | s. | d. | £ | s. | d. | £ | s. | d. |
| 15 | 83 | 2 | 6 | 61 | 1 | 0 | 35 | 10 | 0 |
| 20 | 93 | 6 | 8 | 64 | 0 | 0 | 37 | 0 | 0 |
| 25 | 106 | 9 | 2 | 68 | 10 | 0 | 40 | 0 | 0 |
| 30 | 122 | 1 | 8 | 74 | 0 | 0 | 43 | 0 | 0 |
| 35 | 138 | 19 | 2 | 78 | 19 | 0 | 46 | 0 | 0 |
| 40 | 162 | 6 | 10 | 86 | 0 | 0 | 50 | 4 | 0 |
| 45 | 188 | 10 | 10 | 92 | 18 | 0 | 54 | 0 | 0 |
| 50 | 226 | 5 | 0 | 104 | 2 | 0 | 60 | 13 | 0 |
| 55 | 284 | 3 | 4 | 122 | 14 | 0 | 71 | 11 | 0 |

At every age, therefore, the abstainer has a very great advantage. Mr. Vivian, the President perhaps in some small degree converted into acetic acid, possibly by the action of the mucus or secretion of the stomach. The rate of absorption is not known, and it has been supposed that when given in very large quantities it may not be absorbed at all. As far as I am aware, it has not, however, been recovered from the fæces in any great amount. After absorption it passes into the blood and then throughout the body ; if the observations of Schulinus[*] are correct, it is equally distributed, and does not accumulate, as was formerly supposed, in the liver and nervous tissue. It can easily be detected in all the organs soon after it is taken. It commences to pass out from the body speedily, as it may be detected in the breath soon after it is taken ; it emerges by the lungs, by the skin, in smaller quantities by the urine, and slightly by the bowels, or this may be merely from unabsorbed portions passing out. The amount recoverable from all these channels is usually small,[†] but occasionally, when very large quantities have been taken, the kidneys excrete it largely, so that the specific gravity of the urine has been below that of water, and distillation has given an inflammable fluid.[‡]

Much debate has taken place as to whether all or how much of the alcohol is thus eliminated, and whether any is destroyed in the body. The experiments of Dr Percy, and subsequently of Strauch, and especially of Masing in Buchheim's laboratory at Dorpat, followed as they were by the confirmatory observations of MM. Perrin, Lallemand, and Duroy, seemed at one time to have settled the question, and to have proved that alcohol is very little or not at all destroyed in the body. Since then the criticisms and experiments of Baudot, and especially the observations of Schulinus,[§] Anstie,[‖] Dupré, and Subbotin have again altered the position, and although the experimental evidence is incomplete (chiefly on account of the difficulty of collecting the amount given off by the lungs and skin), the opinion that some, and perhaps much, alcohol disappears in the body is generally admitted.[¶]

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of the Temperance and General Provident Institution, brought before the British Association at Bristol in 1875 the following statistics:—

| Years, | Abstinence Section. | | General Section. | |
|---|---|---|---|---|
| | Expected. | Actual. | Expected. | Actual. |
| 1866–70 (5 years). | 549 | 411 | 1008 | 944 |
| 1871–74 (4 years). | 561 | 390 | 994 | 1033 |
| Totals (9 years). | 1110 | 801 | 2002 | 1977 |

On the gold coast during the Ashantee War the evidence (slight as it was) was decidedly in favour of the teetotallers, (Parkes, On the Issue of a Spirit Ration, p. 28, 1875).

[*] Archiv. der Heilk., 1866, p. 97.

[†] Experiments on this point by Schulinus, Anstie, Dupré, Thudichum, and others, prove that ordinarily the urinary elimination is slight. When it becomes at all marked, or even when it occurs at all, the detection of alcohol by potassium bichromate and sulphuric acid has been proposed by Anstie as an indication of the point when as much alcohol has been taken as can be disposed of by the body.

[‡] A good case is given by Dr Woodman (Medical Mirror, July 1865).

[§] Archiv. der Heilk., 1866.

[‖] Lancet, 1868.

[¶] The amount eliminated by these channels has been variously stated. The latest observations are by Dupré[*] Anstie, and Subbotin.[†] According to Dupré, from experiments on himself, the amount eliminated by the urine and breath (he did not examine the skin) is only a minute fraction of that taken in, and it takes place chiefly in the first nine hours ; subsequently the amount is excessively small. When taken day after day there is no accumulation of alcohol, so that the inference is, that as so little is eliminated almost all must be destroyed. Subbotin's experiments were on rabbits enclosed in a closed chamber through which the air was slowly drawn. Like Dupré, he determined the amount by oxidising the alcohol obtained into acetic

[*] Proceedings of Royal Society, No. 138, p. 268 (1872.) [†] Zeitschrift für Biol. band vii. page 361 (1872).

If alcohol is destroyed in the body, through what stages does it pass? The statement of Duchek, that it forms aldehyde, has been disproved. Its easiest transformation out of the body is into acetic acid; but, when animals are poisoned with alcohol, Buchheim and Masing could detect no acetic acid in the blood; still, the amount would be so small it might be overlooked, or the acetic acid might be soon transformed. Lallemand, Perrin, and Duroy could find no oxalic acid. If it be true that the pulmonary carbonic acid is lessened, it cannot be oxidised to carbonic acid and eliminated by the lungs unless the transformation of some other substance ordinarily furnishing carbonic acid is arrested. The mode of destruction is, in fact, unknown. The only point which throws any light upon it is the slight increase of acidity in the urine during the use of alcohol, which looks as if an acid of some kind were formed out of it.

Present experiments show, then, that some portion passes out, and another, and probably the larger portion, is gradually destroyed. The place where the partial destruction of alcohol occurs is yet doubtful; but it is impossible that the transformation takes place in the various gland-cells in which almost all, or all, the changes in the body take place. As the change out of the body which most easily occurs is the formation of acetic acid, it seems at present most likely that some of the alcohol is thus transformed. The acetic acid would then unite with the soda of the blood, and a carbonate would eventually be formed which would be eliminated with the urine, as is the case when acetates are taken.* This would account for the pulmonary carbonic acid not being increased. If this view be correct, the use of alcohol in nutrition would be limited to the effects it produces, first as alcohol, and subsequently as acetic acid, when it neutralises soda, and is then changed into carbonate.

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acid by chromic acid; but he found that not inconsiderable quantities (nicht unbeträchtliche Mengen) were eliminated through the lungs, and skin, and kidneys in the first five hours. Contrary to Perrin, Lallemand, and Duroy, he found twice as much passed from skin and lungs as from the kidneys. In 11 hours he found 12·6 per cent. was eliminated, and in 24 hours 16 per cent., and he gives reasons for supposing that the difficulties of the experiments (viz., the difficulty of changing all the alcohol into acetic acid; of obtaining the alcohol from the chamber; of regulating the ventilation; and by the diminution of absorption at the end of the experiment, and by the limited time the experiment could be carried on) made the amount actually recovered far less than it should have been. Anstie has made numerous experiments on the urine and sweat, and always found the quantities very minute.

With regard to the length of time the elimination goes on, Dupré found it to be finished within a few hours; Subbotin found that the elimination was not quite ended in 24; Perrin, Lallemand, and Duroy found it to go on for 32 hours. The late Count Wollowicz and myself found that minute quantities could be found in the urine even on the fifth day after a large quantity of brandy had been taken, though the elimination by the lungs ceased much sooner. In some later experiments, with small quantities of beer and wine, I have found the elimination to be finished in 24 hours.

Lieben noticed some years ago, that a substance which had some of the characters of alcohol was found in the urine of persons and animals who had taken none. Count Wollowicz and myself noticed on one occasion that a substance which slightly reduced chromic acid was obtained from the sweat of a man who had taken no alcohol,† though in other cases (E. Smith, British Medical Journal, Nov. 2, 1861) there is certainly no substance of this kind in the sweat. Dupré also found in the urine a substance furnishing acetic acid, forming iodoform, and having a lower specific gravity and a higher vapour tension than pure water. The amount of this substance is so minute that its nature cannot be perfectly made out, but Lieben considers it not to be alcohol, but perhaps to be derived from the odoriferous principles of the urine. Dupré doubts this, and my observation on the sweat shows that it can hardly be so, unless the same odorous substances are passing off by the skin. I doubt whether it is an invariable constituent of urine, as I could find none in the urine of three teetotallers which I lately examined.

* In experiments on large quantities of alcohol I found the acidity of the urine slightly increased. This would quite agree with the above view, as the union of the acetic acid or carbonic acid formed from it, with some of the alkali ordinarily united to other acids, would increase the urinary acidity. The case is, of course, not parallel with that of acetate of potash given by the mouth, which makes the urine alkaline from carbonate, as some alkali in that case is introduced.

† Proceedings Royal Society, No, 118, p. 87 (1870).

The first point only (its effect as alcohol) need be considered—

### *Influence of Alcohol on the Organs.*

1. *On the Stomach.*—In very small quantities it appears to aid digestion; in larger amount it checks it, reddens the mucous membrane, and produces the "chronic catarrhal condition" of Wilson Fox, viz., increase of the connective tissue between the glands; fatty and cystic degeneration of the contents of the glands, and, finally, more or less atrophy and disappearance of these parts.[*] Taken habitually in large quantities, it lessens appetite.

2. *On the Liver.*—The action of small quantities on the amount of bile or glycogenic substances, or on the other chemical conditions of the liver, is not known. Applied directly to the liver by injection into the portal vein, it increases the amount of sugar (Harley). Taken daily in large quantities, it causes either enlargement of the organ by producing albuminoid and fatty deposit, or it causes at once, or following enlargement, increase of connective tissue, and finally, contraction of Glisson's capsule, and atrophy of the portal canals and cells, by the pressure of a shrinking exudation. The exact amount necessary to produce these changes in the liver and stomach has not yet been fixed with precision.

3. *On the Spleen.*—Its action is not known.

4. *On the Lungs.*—It is said to lessen the amount of carbonic acid (and of watery vapour?) in the air of expiration,[†] though there are some discrepancies in experiments with different kinds of spirits. E. Smith, for example, found the expired carbonic acid lessened by brandy and gin, but increased by rum. It is very important these experiments should be repeated, but they show, at any rate, that the usual effect is not to increase the carbonic acid.[‡] In large quantities habitually taken it also alters the molecular constitution of the lungs, as chronic bronchitis and lobar emphysema are certainly more common in those who take much alcohol.

5. *On the Heart and Blood-Vessels.*—Alcohol in healthy persons at first increases the force and the quickness of the heart's action. Dr Anstie [§] has lately confirmed this opinion by careful sphygmographic observations; these effects are still more marked in febrile diseases if alcohol acts favourably (in some febrile cases it appears, from Anstie's observations, not to increase the power of the heart). In a healthy man I found that brandy [||] augmented the rapidity of the pulse 13 per cent., and the force was also increased; taking the usual estimate of the heart's work, its daily excess of work, with 4·8 fluid ounces of absolute alcohol, was equal to 15·8 tons lifted one foot. With claret the results were almost identical. The period of rest of the heart was

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[*] These changes are now considered by Wilson Fox to be closely allied with those occurring in cirrhosis of the liver, and in the contracted and indurated kidney. Dr Fox informs me that the association of those conditions in these organs "has been before him with remarkable frequency." See Diseases of the Stomach, 3d edition, p. 125, footnote; and also Reynold's System of Medicine, vol. ii. p. 869, and footnote.

[†] The effect of red and white French wines and of beer has been very carefully examined by Perrin (Rec. de Mém. de Méd. Mil. 1865, p. 82); a very great diminution in the amount of carbonic acid (from 5·6 to 22 per cent. less being excreted) was noticed in all the experiments. The effect commenced soon, and reached its maximum in the third hour, and ceased in two hours more. The pulse after meals with and without wine had equal power, but after a time the pulse fell more when wine was not taken.

[‡] See Binz Journal of Anatomy and Physiology, May 1874.

[§] In a paper read before the British Association in 1868 (Medical Times and Gazette, September 1868). This paper shows that the sphygmographic indications (combined with the urinary test) may give us a clue to the often difficult question, whether alcohol is doing good or harm in disease.

[||] See papers by Count Wollowicz and myself in Proceedings Royal Society, No. 120 and 132; and another paper by myself, No. 136, for the effect of alcohol on the heart during exercise.

shortened, and its nutrition must therefore have been interfered with. In another man I found from 4 to 8 ounces of brandy produced palpitation and breathlessness. Alcohol causes evident dilatation of the superficial vessels, as shown by the redness and flushing of the skin; and in my experiments sphygmographic observations also proved that the arteries dilated more easily before the fuller current thrown out by the strongly acting heart. If it were not for this yielding of the vessels (produced perhaps by paralysis of the vaso-motor nerves) alcohol would be a most dangerous agent, as either the strong wave would break the vessel, or the heart would not be properly emptied of the blood during the contraction. It seems to me that there must be danger in the use of alcohol when the arteries become rigid in advancing life, if the heart is then susceptible to the action of alcohol. Eventually the vessels of the surface pass into a state of permanent slight enlargement and turgescence; the skin alters in appearance; and, owing to this, persons who take much alcohol soon get the appearance of age. In some diseases, alcohol is said to lessen the frequency of the heart's action; and Anstie found it increase arterial tension. In such cases there must be peculiar nervous conditions with which we are unacquainted. As far as my own observations go, I have found it usually, if not always, increases the frequency of the heart in disease, and in some patients the rapidity of the heart's action has been simply owing to the administration of alcohol. Anstie believes its principal action is on the sympathetic nerve, and the vascular phenomena seem to strengthen this view, while others think it acts especially on the vagus and the heart alone.

6. *On the Blood.*—The amount of fat is either increased, or it is more visible. The chemical changes in the blood are partially arrested.[*]

7. *On the Nervous System.*—In most persons it acts at once as an anæsthetic, and lessens also the rapidity of impressions, the power of thought, and the perfection of the senses. In other cases it seems to cause increased rapidity of thought, and excites imagination, but even here the power of control over a train of thought is lessened. In no case does it seem to increase accuracy of sight; nor is there any good evidence that it quickens hearing, taste, smell, or touch; indeed, Edward Smith's experiments show that it diminishes all the senses. In almost all cases moderate quantities cause a feeling of comfort and exhilaration, which ensues so quickly as to make it probable the local action on the nerves of the stomach has at first something to do with this. Afterwards the increased action of the heart may have an effect. Different spirits act differently on the nervous system, owing probably to the presence of the ethers and oils; some, as samshoo[†] and raki, produce great excitement, followed by profound torpor and depression. Absinthe is also especially hurtful, apparently from the presence of the essential oils of anise, wormwood, and angelica, as well as from the large amount of alcohol. It appears that the properties of absinthe are somewhat different according to the manner in which water is mixed with it, *i.e.*, suddenly or slowly; in the latter case the particles of the absinthe are more divided, are absorbed more

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[*] Harley. Proceedings of Royal Soc., March 1865. No. 62, p. 160.

[†] I was very desirous of ascertaining the exact composition of Chinese Samshoo, and Dr Dupré was so kind as to analyse for me a specimen of the best Samshoo from Singapore. It contained in 100 C.C. 23·91 per cent. of alcohol by weight, and this was made up of 23·874 parts of ethyl alcohol, and ·036 parts of amylic alcohol; the amount of free acid (almost all acetic) was ·105; of residue (sugar almost entirely), 6·01, and of ash, ·06 per cent. Cheap Samshoo gave nearly the same result. There seems to be nothing deleterious here; and from inquiries among soldiers who have served at Hongkong, I am led to doubt whether good Samshoo does produce the effects ascribed to it. I suspect it is the adulterated (with opium, &c.) article which acts so violently. The Cape brandy is of two kinds—the Cape and the Boer brandy; the latter is stronger, and is sometimes called peach brandy; this appears to be the hurtful kind.

easily, and produce greater effects. In all these cases there can be little doubt that alcohol enters into temporary combination with the nervous structure; and the evidence from the impairment of special sense and muscular power, implies that it interferes with the movements of the nervous currents.

8. *On the Muscular System.*—Voluntary muscular power seems to be lessened, and this is most marked when a large amount of alcohol is taken at once; the finer combined movements are less perfectly made. Whether this is by direct action on the muscular fibres, or by the influence on the nerves, is not certain. In very large doses it paralyses either the respiratory muscles, or the nerves supplying them, and death sometimes occurs from the impairment to respiration.

9. *On the Metamorphosis of Tissue.*—This is usually stated to be lessened, and it has been said that there is a diminution in the elimination of nitrogen (as urea), and of carbon (as carbonic acid). But the experiments already referred to by Count Wollowicz and myself[*] prove that the metamorphosis of the nitrogenous tissues is in no way interfered with by dietetic doses. Whether the carbonic acid excretion is really lessened may be also questioned.

10. *On the Temperature of the Body.*—When alcohol is given to healthy animals in full but not excessive doses, the temperature of the body falls. This seems to be shown conclusively by the experiments of Ringer and Rickards, Richardson, Binz, Cuny-Bouvier, and Ruge. In healthy men who have been accustomed to take alcohol in moderate quantities the results are rather contradictory. In a man accustomed to alcohol, Ringer found no change; in two men, temperate, but accustomed to take beer and sometimes spirits, I could not detect any raising or lowering of the thermometer either in the axilla or rectum.[†] Dr Mainzer found no fall of temperature[‡] in trials on himself, but a slight fall in another healthy person. Some experiments by Obernier[§] and by Fokker[‖] are also quite negative. On the other hand, Ringer, Binz, and Bouvier noticed in some healthy persons a decrease of temperature; and though some of the experiments are evidently rather inaccurate, and though the fall of temperature was inconsiderable, it is difficult to refuse belief that in some cases there may be a slight depression of temperature.[¶]

In febrile cases the evidence is almost equally divided. In a man on whom I was experimenting, an attack of catarrh came on with rise of temperature, and alcohol did not apparently in the least affect the heat. O. Weber, Obernier, and Rabow were equally unsuccessful in noting a fall in temperature. Binz and C. Bouvier[**] have, however, produced septic fever in animals, and then lowered the febrile heat by large doses of alcohol, in what appears to have been an unmistakable manner, in several cases.

We may conclude that the effect of moderate doses on temperature in healthy men is extremely slight; there is no increase, and in many persons no decrease. In those in whom there is a slight decrease, the amount is trifling.

11. *On the Action of the Eliminating Organs.*—The water of the urine and the acidity are slightly increased; other ingredients were found in my experi-

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[*] Proceedings Royal Society, Nos. 120–123 and 136.

[†] Ibid.

[‡] Ueber die Einwirkung des Alkohols, Inau. Diss. Bonn., 1870.

[§] Archiv für die ges. Phys. band ii. p. 494.

[‖] Quoted by Husemann, Jahresb. für die ges, Med. 1871, band i. p. 324.

[¶] Binz (*loc. cit.*) finds that small (dietetic ?) doses produce no change; large inebriating doses produce a fall from 3°·5 to 5° F., lasting for four or five hours. Habit, however, produces tolerance. In the body, after death, the temperature often rises, but if alcohol has been administered previously it does not do so;—hence Binz concludes that the effect is arrest of chemical changes in the glands.

[**] See especially Pharmakologische Studien über den Alkohol, von C. Bouvier, Berlin, 1872.

ments to be unaffected, and I cannot but doubt the statements to the contrary. The condition of the skin is not certain. Dr E. Smith thought the perspiration lessened, but Weyrich noticed, after spirits, beer, and wine, a large increase in the insensible cutaneous perspiration; and the enlargement of the vessels of the skin would probably lead to increased transit of fluid.

12. *Remote Effects of Alcohol.*—The degenerative changes which occur so frequently in the stomach, liver, and other organs, by the constant introduction of improper quantities of alcohol into the body,[*] affect also almost all parts of the body. The brain and its membranes, and its vessels, suffer early and principally; and Kremiansky[†] has produced hæmorrhagic meningitis, and pathological changes in the brain-vessels and membranes in dogs by giving them alcohol.[‡] There is no question that several brain diseases, including some cases of insanity, are produced by excess of alcohol.[§] So, also, degenerative changes in the stomach, liver, lungs, and probably in the kidneys,[||] result from immoderate use. To use Dickinson's expressive phrase, alcohol is the very "genius of degeneration." And these alcoholic degenerations are certainly not confined to the notoriously intemperate. I have seen them in women accustomed to take wine in quantities not excessive, and who would have been shocked at the imputation that they were taking too much, although in their case the result proved that for them it was excess. The nature of the degenerative changes appear to be in all cases the same—viz., fibroid and fatty changes.

Considering, also, the great increase in the action of the heart, and the dilatation of the vessels, it can scarcely be doubted that alcohol in excess is one of the agencies causing disease of the circulatory organs.

### *Is Alcohol desirable as an Article of Diet in Health?*

This question is so large and difficult that a satisfactory answer can hardly be given with our present knowledge. The data for passing a judgment are partly physiological, but still more largely empirical.

The obvious useful physiological actions of alcohol are an improvement in appetite, produced by small quantities, and an increased activity of the circulation, which, within certain limits, may be beneficial. It is difficult to perceive proof at present of any other useful action, since it is uncertain whether, during its partial destruction in the system, it gives rise to energy. In cases of disease, in addition to its effect on digestion and circulation, its narcotising influence on the nervous system may be sometimes useful. Beale suggests that it may restrain the rapidity of abnormal growth or development of multiplying cells, and that by such arrest it may possibly diminish bodily temperature; but proof of this has not been given.

The dangerous physiological actions in health, when its quantity is larger, are evidently its influence on the nervous system generally, and on the regulating nerve-centres of the heart, and vaso-motor nerves in particular;[¶]

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[*] A very striking paper on this subject has been lately published by Dickinson; Lancet, November 1872. It paints, in startling colours, the immense degenerative power of alcohol.

[†] Virchow's Archiv, band xlii. p. 338.

[‡] See also the experiments by Magnan (Sur l'Alcoolisme).

[§] Magnan states the two terminations of chronic alcoholism to be *dementia* and *general paralysis.*

[||] Anstie and Dickinson have lately denied that the kidneys suffer in alcoholism in any great degree. It is an open question; but the evidence is, I think, in favour of kidney degeneration being one of the effects of alcoholism. My friend, Dr George Johnson, informs me that out of 200 patients with Bright's disease, from all causes, he found no less than 58 were drunkards.

[¶] This influence is probably a paralysing agency, arising from a direct though transitory union of the alcohol with the nervous substance. Richardson has made the very important the impairment of appetite produced by large doses, the lessening of muscular strength, and remotely the production of degenerations. Except when it lessens appetite, it does not alter the transformation of the nitrogenous tissues, and the elimination of nitrogen; nor can it be held to be absolutely proved to lessen the excretion of carbon. If it did so, this effect in health would be simply injurious.

It is a matter of the highest importance to determine when the limit of the useful effect of alcohol is reached. The experiments are few in number, but are tolerably accurate. From experiments made by Dr Anstie, an amount of one fluid ounce and a half (42·6 C.C.) caused the appearance of alcohol in the urine, which Anstie regards as a sign that as much has been taken as can be disposed of by the body. The late Count Wollowicz and myself obtained almost precisely the same result. When only one fluid ounce of absolute alcohol was given none could be detected in the urine. We found that in a strong healthy man, accustomed to alcohol in moderation, the quantity given in twenty-four hours that begins to produce effects which can be considered injurious is something between one fluid ounce (= 28·4 C.C.) and two fluid ounces (56·8 C.C.) The effects which can then be detected are slight, but evident narcosis, lessening of appetite, increased rapidity of rise in the action of the heart, greater dilatation of the small vessels as estimated by the sphygmograph, and the appearance of alcohol in the urine. These effects manifestly mark the entrance of that stage in the greater degrees of which the poisonous effects of alcohol become manifest to all.

It may be considered, then, that the limit of the useful effect is produced by some quantity between 1 and 1½ fluid ounces in twenty-four hours. There may be persons whose bodies can dispose of larger quantities; but as my experiments were made on two powerful healthy men, accustomed to take alcohol, the average amount was more likely to be over than under stated. In women, the amount required to produce decided bad effects must, in all probability, be less. For children there is an almost universal consent that alcohol is injurious, and the very small quantity which produces symptoms of intoxication in them indicates that they absorb it rapidly and tolerate it badly.

Assuming the correctness of these experimental data, which, though not extensive, are yet apparently exact, it is evident that moderation must be something below the quantities mentioned; and considering the dangers of taking excess of alcohol, it seems wisest to assume 1 to 1½ fluid ounces of absolute alcohol in twenty-four hours as the maximum amount which a healthy man should take. It must be admitted that this is provisional, and that more experiments are necessary; but it is based on the only safe data we possess. One ounce is equivalent to 2 fluid ounces of brandy (containing 50 per cent. of alcohol) or to 5 ounces of the strong wines (sherries, &c., 20 per cent. of alcohol); or to 10 ounces of the weaker wines (clarets and hocks, 10 per cent. of alcohol); or to 20 ounces of beer (5 per cent. of alcohol.) If these quantities are increased one-half, 1½ ounce of absolute alcohol will be taken, and the limit of moderation for strong men is reached. I believe that this standard is fairly correct; since, from inquiries of many healthy men who take alcohol in moderation, I find that they seldom exceed the above amounts. Women, no doubt, ought to take less; and alcohol in any shape only does harm to healthy children.

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discovery that the alcohols, such as the butyl, amyl, and hexyl alcohols, which contain more carbon, produce a much greater effect on the nervous system than methyl and ethyl alcohol. There are greater muscular tremors and stupor, and these effects increase regularly with the increase of carbon and lessening volatility.

Another question now arises, to which it is more difficult to reply. Is alcohol, even in this moderate amount, necessary or desirable; are men really better and more vigorous, and longer lived with it than they would be without any alcohol? If distinctly hurtful in large quantities, is it not so in these smaller amounts?

There is no difficulty in proving, statistically, the vast loss of health and life caused by intemperance; and the remarkable facts of the Provident Institution (see page 291) show the great advantage total abstainers have over those who, though not intemperate, use alcohol more freely. But it is almost impossible, at present, to compare the health of teetotallers with those who use alcohol in the moderate scale given above. In both classes are found men in the highest health, and with the greatest vigour of mind and body; in both are to be found men of the most advanced age. If the question is looked at simply as a scientific one, I do not see how an answer can be at present given. Failing, as it appears to me, in accurate information on this point, the usual arguments for and against the use of alcohol cannot be held to settle the point. These are—

(*a*) That the universality of the habit of using some intoxicating drink proves utility. This seems incorrect,* since whole nations (Mohammedan and Hindoo) use no alcohol or substitute; and since the same argument might prove the necessity of tobacco, which for this generation, at any rate, is clearly only a luxury. The wide-spread habit of taking intoxicating liquids merely proves that they are pleasant.

(*b*) That if not necessary in healthy modes of life, alcohol is so in our artificial state of existence amid the pressure and conflict of modern society. This argument is very questionable, for some of our hardest workers and thinkers take no alcohol. There are also thousands of persons engaged in the most anxious and incessant occupations who are total abstainers, and, according to their own account, with decided benefit.

(*c*) That though it may not be necessary for perfectly healthy persons, alcohol is so for the large class of people who live on the confines of health, whose digestion is feeble, circulation languid, and nervous system too excitable. It must be allowed, I think, there are some persons of this class who are benefited by alcohol in small quantities, and chiefly in the form of beer or light wine. Unless these persons wifully deceive themselves, they feel better and are better with a little alcohol.

(*d*) That common experience on the largest scale shows that alcohol in not excessive quantities cannot be an agent of harm; that it is and has been used by millions of persons who appear to suffer no injury, but to be in many cases benefited, and therefore that it must be in some way a valuable adjunct to food. A grand fact of this kind must, it is contended, override all objections based on physiological data, which are confessedly incomplete, and which may have left undiscovered some special useful action. It must be admitted that this is a very strong argument, and that it seems incredible that a large part of the human race should have fallen into an error so gigantic as that of attributing great dietetic value to an agent which is of little use in small quantities, and is hurtful in large. At first sight the common sense of mankind revolts at such a supposition, but the argument, though strong, is not conclusive; and unfortunately we know that in human affairs no extension of belief, however wide, is *per se* evidence of truth.

(*e*) That though a man can do without alcohol under ordinary circumstances, there are certain conditions when it is useful. It will be necessary to see, then, what is the evidence on this point.

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* Most nations, however, if not all, use some sedative, which may be considered to take the place of alcohol. (F. de C.)

*Evidence on the Use of Alcohol under certain conditions.*[*]

*Great Cold.*—There is singular unanimity of opinion on this point; all observers condemn the use of spirits, and even of wine or beer, as a preventive against cold. In the Arctic regions we have on this head the evidence of Sir John Richardson, Mr Goodsir (in Sir J. Franklin's first voyage), Dr King, Captain Kennedy (in the last search for Sir J. Franklin, when the whole crew were teetotallers), Dr Rae, Dr Kane, Dr Hayes (surgeon of the Kane expedition), and others. Dr Hayes, indeed, says in his last paper (1859), that he will not only not use spirits, but will take no man accustomed to use them; and that if "imperious necessity obliges him to give spirits, he will give them in small doses frequently, as the excitant action is followed by a very dangerous depression."[†] In the Antarctic regions, and in the cold whaling grounds, we have the strong evidence of Dr Hooker to the same purport, and the customs of the many teetotal whalers. Ulloa long ago noticed the same thing in the ascent of Pichincha.[‡] In North America, the Hudson's Bay Company entirely excluded spirits, partly, no doubt, to prevent their use among the Indians, but partly, in all probability, from experience of their inutility. Dr Carpenter quotes from Dr Knüll a statement that the Russian army on the march in cold weather not only use no spirits, but no man who has lately taken any is allowed to march. The guides at Chamouni and the Oberland, when out in the winter, have invariably found spirits hurtful; they take only a little light wine (Forbes). The bathing men at Dieppe, who are much exposed to cold from long standing in the sea, also find that spirits are hurtful, and take only a little weak wine (Levy).

*Great Heat.*—The evidence here also is almost equally conclusive against the use of spirits or beverages containing much alcohol. Dr Carpenter has assembled the most conclusive testimony from India, Brazil, Borneo, Africa, and Demerara. The best authorities on tropical diseases speak as strongly; Robert Jackson, Ranald Martin, Henry Marshall, and many others. It seems quite certain, also, that not only is heat less well borne, but that insolation is predisposed to.

The common notion that some form of alcoholic beverage is necessary in tropical climates is, I firmly believe, a mischievous delusion. I brought to Dr Carpenter's notice the case of the 84th Regiment, in which I formerly served, which from the years 1842 to 1850 numbered many teetotallers (at one time more than 400) in its ranks; and the records of this regiment show that, both on common tropical service and on marches in India, the teetotallers were more healthy, more vigorous, and far better soldiers than those who did not abstain.[§] The experience of almost every hunter in India will be in accordance with this.

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[*] I have borrowed largely from Carpenter's admirable Essay on Temperance, and his other writings, and also from Spencer Thomson's useful work on the same subject, as well as from many other writers.

[†] Some Arctic voyagers, however, are strongly impressed with the value of rum under certain circumstances (Admiral Richards). The experience of the expedition of 1875-6 seems to have shown that it was partially useful given the last thing at night, as enabling the men to get off their frozen clothing, but it had no effect in warding off scurvy. Binz says that alcohol may be useful in damp and cold, because the tissue change is greater, and we can thus moderate it.

[‡] He says (Adams' translation, 1807, vol. i. p. 219), "at first we imagined that drinking strong liquors would diffuse a heat through the body, and consequently render it less sensible of the painful sharpness of the cold; but to our surprise we felt no manner of strength in them, nor were they any greater preventative against the cold than common water."

[§] See Carpenter's Physiology of Temperance for full details. The officers, who by their

On this point the greatest army surgeons have spoken strongly (Jackson especially, and Martin); and yet nothing is more common, even at the present day, than to hear officers, both in India and the West Indies, assert that the climate requires alcohol. These are precisely the climates where alcohol is most hurtful.*

With regard to service and exercise in the tropics, we have the strong testimony of Ranald Martin that warm tea is the best beverage; and this will be corroborated, I believe, by every one who has made long marches, or hunting excursions, in India, and has carefully observed what kind of diet best suited him.

To cite a well-known individual instance of great exertion in a hot climate, Robert Jackson marched 118 miles in Jamaica, carrying a load equal to a soldier's, and decided that "the English soldier may be rendered capable of going through the severest military service in the West Indies; and that temperance will be one of the best means of enabling him to perform his duty with safety and effect. The use of ardent spirits is not necessary to enable a European to undergo the fatigue of marching in a climate whose mean temperature is from 73° to 80°. I have always found the strongest liquors the most enervating."

*Bodily Labour.*—A small quantity of alcohol does not seem to produce much effect, but more than two fluid ounces manifestly lessens the power of sustained and strong muscular work. In the case of a man on whom I experimented, 4 fluid ounces of brandy (= 1·8 fluid ounces of absolute alcohol) did not apparently affect labour, though I cannot affirm it did not do so; but 4 ounces more given after four hours, when there must have been some elimination, lessened muscular force; and a third 4 ounces, given four hours afterwards, entirely destroyed the power of work. The reason was evidently twofold. There was, in the first place, narcosis and blunting of the nervous system—the will did not properly send its commands to the muscles, or the muscles did not respond to the will; and secondly, the action of the heart was too much increased, and induced palpitation and breathlessness, which put a stop to labour. The inferences were, that even any amount of alcohol, although it did not produce symptoms of narcosis, would act injuriously by increasing unnecessarily the action of the heart, which the labour alone had sufficiently augmented.† I believe these experiments are in accord with common experience, which shows that men engaged in very hard labour, as iron-puddlers, glass-blowers, navvies on piece-work, and prize-fighters during training, do their work more easily without alcohol.

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example and precept, produced this great effect in a regiment in India, and proved that men are healthier and happier in India without any alcoholic beverage, were Lieut-Colonel Willington, Captain (now General Sir David) Russell, and Lieut. and Adjutant Seymour, an officer of the greatest promise, who died from dysentery, contracted during the mutiny.

* Binz holds that in hot climates, or in hot weather, it is pernicious, as interfering with the tissue change, which is already insufficient.

† In experimenting on another healthy man I came to the following interesting result. The exercise and diet being uniform during a period of ten days, the mean daily pulse (nine two-hourly observations) was 70·65. Severe exercise being then taken during another period of ten days for two hours in the morning, in addition to what had previously been taken, the pulse in those two hours was augmented 16 beats per minute over the corresponding period; it fell, however, in the subsequent hours below the mean of the corresponding period, so that the mean pulse of the day was 70·42 per minute, the same as in the ten days' period before the additional exercise. The heart, in fact, completely compensated itself, and the work done by it was the same on days of moderate and of severe exercise. Now alcohol would have disturbed this adjustment, and would have kept the heart beating more rapidly than it should do. The compensation would not have been produced. In more recent experiments, in which the effects of rum, meat extract, and coffee were observed, it was found that marching was done least easily with rum, the stimulant effect passing quickly off, and leaving the man less able to finish the work before him. (On the Issue of a Spirit Ration in the Ashanti Campaign, Parkes, 1875).

In the exhaustion following great fatigue, alcohol may be useful or hurtful according to circumstances. If exertion must be resumed, then the action of the heart can be increased by alcohol and more blood sent to the muscles; of course, this must be done at the expense of the heart's nutrition, but circumstances may demand this. In the case of an army, for example, called on to engage the enemy after a fatiguing march, alcohol might be invigorating. But the amount must be small, *i.e.*, much short of producing narcosis (not more than ½ fluid ounce of absolute alcohol), and, if possible, it should be mixed with Liebig's meat extract, which, perhaps on account of its potash salts, has a great power of removing the sense of fatigue.

About two ounces of red claret wine with two teaspoonfuls of Liebig's extract and half pint of water is a very reviving draught, and if it could be issued to troops exhausted by fatigue, would prove a most useful ally.

But when renewed exertion is not necessary it would appear most proper after great fatigue to let the heart and muscles recruit themselves by rest; to give digestible food, but to avoid unnecessary and probably hurtful quickening of the heart by alcohol.

*Mental Work.*—In spite of much large experience, it is uncertain whether alcohol really increases mental power. The brain circulation is no doubt augmented in rapidity; the nervous tissues must receive more nutriment, and for a time must work more strongly. Ideas and images may be more plentifully produced, but it is a question whether the power of clear, consecutive, and continuous reasoning is not always lessened. In cases of great exhaustion of the nervous system, as when food has been withheld for many hours and the mind begins to work feebly, alcohol revives mental power greatly, probably from the augmented circulation. But, on the whole, it seems questionable whether the brain finds in alcohol a food which by itself can aid in mental work.

*Deficiency of Food.*—When there is want of food, it is generally considered that alcohol has a sustaining force, and possibly it acts partly by keeping up the action of the heart, and partly by deadening the susceptibility of the nerves. It was formerly supposed that it lessened tissue-change, and thus curtailed the waste of the body; but this is not true of the nitrogenous tissues, and is not yet quite certain in respect of the carbonaceous. It seems unlikely that alcohol would be applied differently during starvation and during usual feeding.

Cases are recorded in which persons have lived for long periods on almost nothing but wine and spirits. In most cases, however, some food has been taken, and sometimes more than was supposed, and in all instances there has been great quietude of mind and body. It seems very doubtful whether in any case nothing but alcohol has been taken; and, in fact, we may fairly demand more exact data before weight can be given to this statement.

*The Exposures and Exertions of War.*—On this point, also, there is considerable unanimity of opinion. The greatest fatigues, both in hot and cold climates, have been well borne—have been, indeed, best borne—by men who took no alcohol in any shape, and some instances may be quoted.

In the American War of Independence in 1783, Lord Cornwallis made a march of over 2000 miles in Virginia, under the most trying circumstances of exposure to cold and wet; yet the men were remarkably healthy, and among the causes for this health, Chisholm states that the necessary abstinence from strong liquors was one.

In 1794–95 occurred the Maroon war in Jamaica, where almost for the first time in West Indian warfare the troops were remarkably healthy, though the campaign was very arduous, and in the rainy season, and there were no tents.

The perfect health of the troops may partly have been owing to the climate of the hills (2000 feet above the sea), but it was chiefly attributed to the fact that the men could obtain no spirits or alcoholic liquid of any kind.

In 1800, an English army proceeding from India to Egypt, to join Sir Ralph Abercromby, marched across the desert, from Kossier on the Red Sea, and descended the Nile for 400 miles. Sir James M'Grigor* says that the fatigue in this march has perhaps never been exceeded by any army, and goes on to remark—

> "We received still farther confirmation of the very great influence which intemperance has as a cause of disease. We had demonstration how very little spirits are required in a hot climate to enable a soldier to bear fatigue, and how necessary a regular diet is.
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> "At Ghenné, and on the voyage down the Nile (on account of the difficulties of at first conveying it across the desert, the men had no spirits delivered out to them, and I am convinced that from this not only did they not suffer, but that it even contributed to the uncommon degree of health which they at this time enjoyed. From two boats the soldiers one day strayed into a village, where the Arabs gave them as much of the spirit which they distil from the juice of the date-tree as induced a kind of furious delirium. It was remarked that, for three months after, a considerable number of these men were in the hospitals."

Dr Mann,† one of the few American surgeons in the war of 1813–14 who have left any account of that contest, thus writes :—

> "My opinion has long been that ardent spirits are an unnecessary part of a ration. Examples may be furnished to demonstrate that ardent spirits are a useless part of a soldier's ration. At those periods during the revolutionary war, when the army received no pay for their services, and possessed not the means to procure spirits, it was healthy. The 4th Massachusetts Regiment, at that eventful period when I was the surgeon, lost in three years by sickness not more than five or six men. It was at a time when the army was destitute of money. During the winter 1779-80 there was only one occurrence of fever in the regiment, and that was a pneumonia of a mild form. It was observable in the last war, from December 1814 to April 1815, the soldiers at Plattsburgh were not attacked with fevers as they had been the preceding winters. The troops during this period were not paid—a fortunate circumstance to the army, arising from want of funds. This embarrassment, which was considered a national calamity, proved a blessing to the soldier. When he is found poor in money, it is always the case that he abounds in health—a fact worth recording."

No testimony can be stronger than that given by the late Inspector-General Sir John Hall, K.C.B. He says‡ :—

> "My opinion is, that neither spirit, wine, nor malt liquor is necessary for health. The healthiest army I ever served with had not a single drop of any of them; and although it was exposed to all the hardships of Kaffir warfare at the Cape of Good Hope, in wet and inclement weather, without tents or shelter of any kind, the sick-list seldom exceeded one per cent.; and this continued not only throughout the whole of the active operations in the field during the campaign, but after the men were collected in standing camps at its termination; and this favourable state of things continued until the termination of the war. But immediately the men were again quartered in towns and fixed posts, where they had free access to spirits, an inferior species of brandy sold there, technically called 'Cape Smoke,' numerous complaints made their appearance among them.
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> "In Kaffraria the troops were so placed that they had no means of obtaining liquor of any kind; and all attempts of the 'Winklers' to infringe the police regulations were so summarily and heavily punished by fines and expulsion, that the illicit trade was effectually suppressed by Colonel Mackinnon, the Commandant of British Kaffraria; and the consequence was, that drunkenness, disease, crime, and insubordination were unknown; and yet that army was frequently placed in the very position that the advocates for the issue of spirits would have said required a dram.
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> "Small as the amount of sickness and mortality was in the Crimea, during the winter 1855-56, they would have been reduced one-half, I am quite sure, could the rule that was observed in Kaffirland have been enforced there."

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* Medical Sketches of the Expedition to Egypt, p. 10.

† Hamilton, Military Surgery, p. 61.

‡ Medical History of the War in the Crimea, vol. i. p. 504.

In the same Kaffir war (1852), a march was made by 200 men from Graham's Town to Bloomfronthein, and back; 1000 miles were covered in seventy-one days, or at the rate of nearly 15 miles daily; the men were almost naked, were exposed to great variations of temperature (excessive heat during day; while at night water froze in a bell-tent, with twenty-one men sleeping in it); and got as rations only biscuit (meat 1½ lb), and what game they could kill. For drink they had nothing but water. Yet this rapid and laborious march was not only performed easily, but the men were "more healthy than they had had ever been before; and after the first few days, ceased to care about spirits. No man was sick till the end of the march, when two men got dysentery, and these were the only two who had the chance of getting any liquor."

In the last New Zealand war, Dr Neill (Staff Assistant-Surgeon) found that the troops marched better, even when exposed to wet and cold, when no spirits were issued, than when there was a spirit ration.

In the late expedition to the Red River, under Sir Garnet Wolseley, no alcoholic liquid was issued. Two accounts of this remarkable march have been published—one by Captain Huyshe,* and the other by an officer who wrote an interesting account of the march in *Blackwood's Magazine.*† Captain Huyshe says :—

> "Although it was an unheard-of thing to send off an expedition into a wilderness for five month without any spirits, still as the backwoodsman was able to do hard work without spirits, it was rightly thought that the British soldiers could do the same. The men were allowed a large daily ration of tea, 1 oz. per man—practically as much as they could drink; and, as I am now on this subject of bohea *versus* grog, I may as well state that the experiment was most successful. The men of no previous expedition have ever been called upon to perform harder or more continuous labour for over four months. . . . They were always cheery, and worked with a zealous will that could not be surpassed. This expedition would have been a bright era in our military annals had it no other result than that of proving the fallacy hitherto believed in of the necessity of providing our men when in the field with intoxicating liquors."

The writer in *Blackwood's Magazine* says :—

> "The men were pictures of good health and soldier-like condition whilst stationed at Prince Arthur's Landing and the other larger camps. The men had fresh meat, bread, and potatoes every day. No spirits were allowed throughout the journey to Fort Garry, but all ranks had daily a large ration of tea. This was one of the very few military expeditions ever undertaken by English troops where intoxicating liquors formed no part of the daily ration. It was an experiment based upon the practice common in Canada, where the lumbermen, who spend the whole winter in the backwoods, employed upon the hardest labour, and exposed to a freezing temperature, are allowed no spirits, but have an unlimited quantity of tea. Our old-fashioned generals accept, without any attempt to question its truth, the traditional theory of rum being essential to keep the British soldier in health and humour. Let us hope that the experience we have acquired during the Red River expedition may have buried for ever this old-fogyish superstition. Never have the soldiers of any nation been called upon to perform more unceasingly hard work; and it may be confidently asserted without dread of contradiction, that no men have ever been more cheerful or better behaved in every respect. No spirit ration means no crime; and even the doctors who anticipated serious illness from the absence of liquor, will allow that no troops have ever been healthier than they were from the beginning to the end of the operation. With the exception of slight cases of diarrhœa, arising from change of diet, it may be said that sickness was unknown amongst us."

Sir Garnet Wolseley, who commanded in this remarkable expedition, speaks ("Soldiers' Pocket Book," 2d edition, p. 172) very strongly against the rum ration, and says that, by substituting tea for rum, the health and efficiency of the men are increased, "their disciplins will improve as their moral tone is raised, engendering a manly cheerfulness that spirit-drinking armies know nothing of."

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* Journal, United Service Institution, 1871, vol. xv. p. 74.
† January 1871, p. 64.

In the Ashanti campaign of 1874 observations were carefully recorded by several officers, much of the information obtained being given in the book "On the Issue of a Spirit Ration during the Ashanti Campaign of 1874" (Parkes). The conclusions arrived at were—1. That abstinence did not render those who abstained more sickly as a whole or more liable to malarious fever; nor did it interfere with their powers of marching. 2. The issue of a ration of rum seemed to do good when given at the end of the day before going to rest. 3. That the quantity (2½ oz.) was amply sufficient. On the whole the *necessity* for the ration was by no means proved, although some officers returned rather shaken in their previous belief that alcohol was absolutely unnecessary in a military expedition.

In sieges, which are perhaps more trying to men than campaigning in the open field, the advantage of temperance has, on two occasions, been very marked. In the great siege of Gibraltar, Sir George Eliott, who was a teetotaller, enforced the most rigid temperance, and the long and arduous blockade was passed through with remarkably little sickness. At the siege of Jellalabad, in Affghanistan, the "illustrious garrison" were quite destitute of all alcoholic liquors; and, to the astonishment of the officers, the Europeans never had been so healthy, cheerful, martial, and enduring, and free from crime. During the Indian mutiny many regiments were debarred from spirits for a long time, and were much healthier than when they got them.

In fact, it may be confidently asserted that in war, spirits especially, and indeed all alcoholic liquors, are better avoided; and the phrase of an American army surgeon in the late civil war, who noticed how great was the improvement when spirit prohibition was enforced, is fully justified by our own experience—"The curse of an army is intoxicating liquors; the spirit ration is the great source of all this mischief."

When debarred from spirits and fermented liquids, men are not only better behaved, but are far more cheerful, are less irritable, and endure better the hardships and perils of war. The courage and endurance of a drunkard are always lessened; but in a degree far short of drunkenness, spirits lower, while temperance raises, the boldness and cheerfulness of spirit which a true soldier should possess.*

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* The custom of giving rations of spirits to soldiers and sailors (even now not altogether discontinued), was one of those incredible mistakes which are only made worse by the explanation that it was done to please the men, and cover neglect in other ways. If any one wishes to see what our army was in former days, and how our dreadful military regulations made men drunkards in spite of themselves, I may refer them to an old Peninsular surgeon's (William Fergusson's) Notes and Recollections of a Professional Life (1846). "During the last war" (he says, p. 74), "our sailors and soldiers appeared to live for the purpose of getting drunk; with them it seemed to be the chief article of their creed—the chief end of life. . . . . 'Grog, grog,' was still the cry; I have seen it, as it were, forced down the throats of the innocent negro boy and the uncorrupted young recruit. We seemed to believe that the term *aqua vitæ* was its true designation. Every one was to have it; no matter what the age, the colour, the country, or the breeding. Our Portuguese allies in the Peninsula were the soberest of mankind. They liked their own weak country wine to dilute their food, but that would not do for us. We actually sent for the rum of the West Indies and gave it them; and at the battle of Busaco, I saw a party of Portuguese artillery, as soon as the rum ration was served, as if they had been possessed by devil (and they actually were possessed by a devil in the shape of alcohol) draw their swords and fight with one another, when actually under the fire of the enemy" (p. 85).

He cites numerous most lamentable facts, and well concludes that "our canteen system will in after times be viewed with horror and astonishment, at its folly, corruption, and wickedness."

I do not recall these opinions without a motive. There is too much reason to fear that many officers still believe that soldiers must have spirits. Fergusson says that "the exceeding vulgarity of the prejudice that ardent spirits impart strength and vigour to the human frame is disgraceful to educated men;" and yet this belief is still actually held by many persons in authority. Although in the army, drinking is the great source of all crime and insubordination; although even within the last twenty years we have had one if not more instances that, even during an assault, men will sacrifice anything, even their honour, to obtain spirits;

Looking back to this evidence, it may be asked, Are there any circumstances of the soldier's life in which the issue of spirits is advisable, and if the question at any time lies between the issue of spirits and total abstinence, which is the best?

To me there seems but one answer. If spirits neither give strength to the body, nor sustain it against disease—are not protective against cold and wet, and aggravate rather than mitigate the effects of heat—if their use even in moderation increase crime, injure discipline, and impair hope and cheerfulness—if the severest trials of war have been not merely borne, but most easily borne, without them—if there is no evidence that they are protective against malaria or other diseases—then I conceive the medical officer will not be justified in sanctioning their issue under any circumstances.

The terrible system which in the East and West Indies made men drunkards in spite of themselves, and which by the issue of the morning dram did more than anything else to shatter the constitutions of the young soldiers, is now becoming a thing of the past. But the soldier is still permitted to get spirits too easily, and is too ignorant of their fatal influence on his health. Still the British army bears the unhappy character of the most intemperate army in Europe, and it is certain that its moments of misconduct and misfortune have been too frequently caused by the unrestrainable passion for drink. Remembering all these things, and how certainly it has been proved that drunkenness increases the spread of syphilis, it is not too much to say that the repression of this vice should be one of the chief duties of every officer in the army. Moderation should be encouraged by precept and example; wholesome beer and light wine should be invariably substituted for spirits, and if these cannot be procured, it may safely be said that the use of tea, coffee, or simple water is preferable to spirits under all circumstances of the soldier's life.

*Resistance to Disease.—Malaria.*—There are instances for and against the view that spirits are useful against malaria. On both sides the evidence is defective; but there are so many cases in which persons have been attacked with malarious disease who took spirits, that it is impossible to consider the preventive powers great, even if they exist at all. On the other hand, when teetotallers have escaped malaria (as in the instance recorded by Drake),* there have been other circumstances, such as more abundant food and better lodging, which will explain their exemption. The probability is, that the reception and action of malaria are not influenced by the presence or absence of alcohol in the blood, unless the amount of alcohol is so great as to lessen the amount of food taken.

*Yellow Fever.*—It is a general opinion in New Orleans and Mobile that the victims of yellow fever are chiefly those who drink freely (Drake). The old West Indian experience is to the same effect.

*Cholera.*—Intemperance, *per se*, has no influence, and teetotalism does not guard against cholera. When a regiment is attacked with cholera, and the men take to drinking, a number of pseudo-cases come into hospital of vomiting and

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although the best officers know that this is the one point on which they cannot depend on their men, far too little has been done to make our army temperate. I do not mean to say that nothing has been done; on the contrary, in this, as in all things, progress has been made, but the measures are not sufficient to control an evil so gigantic. It is the same thing in civil life; there is no question that more disease is, directly and indirectly, produced by drunkenness than by any other cause, and that the moral as well as the physical evils proceeding from it are beyond all reckoning; and yet the attempts of the Legislature to set some bounds to intemperance have been and are opposed with a bitterness which could only be justified if the degradation and not the improvement of mankind was desired.

* On the Interior Valley of North America.

cramps, which are often returned as cholera, but I believe they seldom if ever pass into true cholera.

*Dysentery.*—It has been supposed, from some statistics for 1847, published in the *Fort George Gazette*, that teetotallers were more subject to dysentery, but the error was committed of not estimating sufficiently the influence of a particular station (Secunderabad), where it is so happened a number of teetotallers were stationed during an outbreak of dysentery. The conditions of the station were to blame, not the habits of the men.

In none of the conditions now enumerated is there any evidence that alcohol is desirable.

### *Conclusion as to the Use of Alcohol.*

The facts now stated make it difficult to avoid the conclusion that the dietetic value of alcohol has been much over-rated. It does not appear to me possible at present to condemn alcohol altogether as an article of diet in health; or to prove that it is invariably hurtful, as some have attempted to do. It produces effects which are often useful in disease and sometimes desirable in health, but in health it is certainly not a necessity, and many persons are much better without it. As now used by mankind, it is infinitely more powerful for evil than for good; and though it can hardly be imagined that its dietetic use will cease in our time, yet a clearer view of its effects must surely lead to a lessening of the excessive use which now prevails. As a matter of public health, it is most important that the medical profession should throw its great influence into the scale of moderation; should explain the limit of the useful power, and show how easily the line is passed which carries us from the region of safety into danger, when alcohol is taken as a common article of food.*

### *Dietetic Use of Alcoholic Beverages.*

In the previous remarks, the effect of alcohol only has been discussed, but beer and wine contain other substances besides alcohol.

In wine there are some albuminous substances, much sugar (in some wines), and other carbo-hydrates, and abundant salts. Whether it is that the amount of alcohol is small, or whether the alcohol be itself, in some way, different from that prepared by distillation,† or whether the co-existence of carbo-hydrates and of salts modifies its action, certain it is that the moderate use of wine, which is not too rich in alcohol, does not seem to lead to those profound alterations of the molecular constitution of organs which follow the use of spirits, even when not taken largely. Considering the large amounts of vegetable salts which most wines contain, it may reasonably be supposed that they play no unimportant part in giving dietetic value to wine. Indeed, it is quite certain that, in one point of view, they are most valuable; they are highly anti-scorbutic, and the arguments of Lind and Gillespie, for the introduction of red wine into the royal navy instead of spirits, have been completely justified in our own time by both French and English experience.

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* A great evil is growing up in India, which now could be checked, but which we shall be powerless to meet in a few years. The Hindoos, formerly the most temperate of races, are rapidly becoming addicted to drink. This is said to be partly owing to the regulations of the Government permitting, and even encouraging the sale of spirits, although the alcoholic liquors form no part of the ordinary food of the people, and therefore their prohibition is not difficult; and partly from the bad example of the Europeans in India, who, as the dominant race, are impressing more and more the nations whom they control. It seems a matter which our statesmen may well look into, for it involves the happiness of many nations.

† Thudichum and Dupré could not, however, trace any difference between the alcohol in wines and that derived from other sources.

It is now certain that with the same diet, but giving in one case red wine, in another rum, the persons on the latter system will become scorbutic long before those who take the wine. This is a most important fact, and in a campaign the issue of red wines should never be omitted. The ethers may also be important if, as indicated by Bernard, and recently pointed out by Dr B. Forster (*Brit. Med. Journal*, Nov. 1868), they excite the flow of the pancreatic secretion, and thereby promote the absorption of fat.

In beer, there appear to be four ingredients of importance, viz., the extractive matters and sugar, the bitter matters, the free acids, and the alcohol. The first, no doubt, are carbo-hydrates, and play the same part in the system as starch and sugar, appropriating the oxygen, and saving fat and albuminates from destruction. Hence, one cause of the tendency of persons who drink much beer to get fat. The bitter matters are supposed to be stomachic and tonic; though it may be questioned whether we have not gone too far in this direction, as many of the highest-priced beers contain now little else than alcohol and bitter extract. The action of the free acids is not known; but their amount is not inconsiderable; and they are mostly of the kind which form carbonates in the system, and which seem to play so useful a part. The salts, especially potassium and magnesium phosphates, are in large amount.

It is evident that in beer we have a beverage which can answer several purposes—viz., can give a supply of carbo-hydrates, of acid, of important salts, and of a bitter tonic (if such be needed) independent of its alcohol, but whether it is not a very expensive way of giving these substances is a question.

In moderation, it is no doubt well adapted to aid digestion, and to lessen to some extent elimination of fat. It may be inferred that beer will cause an increase of weight of the body, by increasing the amount of food taken in, and by slightly lessening metamorphosis; and general experience confirms those inferences. When taken in excess, it seems to give rise to gouty affections more readily even than wine.

In spirits, alcohol is the main ingredient, chiefly in the form of ethyl-alcohol, though there are small amounts of propyl-, butyl-, and in some cases amyl-alcohols. In addition, there are sometimes small quantities of ether; and, in some cases, essential oils (as apparently in absinthe, and in one kind of Cape brandy), which have a powerful action on the nerves. But spirits are, for the most part, merely flavoured alcohol, and do not contain the ingredients which give dietetic value to wine and beer. They are also more dangerous, because it is so easy to take them undiluted, and thus to increase the chance of damaging the structure and nutrition of the albuminous structures with which they come first in contact. There is every reason, therefore, to discourage the use of spirits, and to let beer and wines, with moderate alcoholic power, take their place.

## SECTION II.

## NON-ALCOHOLIC BEVERAGES.

### SUB-SECTION I.—COFFEE.

Unroasted coffee contains much cellulose (34 per cent.), fat (10 to 13 per cent.), sugar and dextrin, and vegetable acid (15·5), and legumin (10 per cent.) There is also a solid acid, aromatic oil in small quantities, caffein, and ash, the chief ingredients of which are potash and phosphoric acid. The total amount of caffein (free and combined), according to Payen, is about 1·736 per cent.; but this is more than other observers have found. In roasted coffee berries the average of Boutron and Robiquet's analyses gives ·238 per cent. of caffein

Aubert* has given the amount as from ·709 to ·849 per cent., and Witte makes it ·666 per cent.; Graham, Stenhouse, and Campbell state it as ·87 per cent. It may be assumed to be ·75 per cent. on an average. Aubert found that roasting coffee to any extent caused very little loss of caffein. The caffein is extracted easily by benzol or by chloroform.†

When coffee is roasted it swells, but becomes lighter (15 to even 25 per cent. if the coffee is dark roasted). The sugar is changed into caramel, the peculiar aroma is developed, the union between the caffein and the caffee-gallic acid is broken up; several gases are formed, viz., carbonic acid (in greatest amount), carbonic oxide, and nitrogen. It is owing to these gases that the roasted coffee swells so much. (Coulier, *Recueil de Mémoires de Méd. Mil.*, Juin 1864, p. 508). In the infusion almost all the caffein is found, according to Aubert, while others say about one-half is lost. Aubert has found that in a cup of coffee made with 16·66 grammes, or ·587 ounce avoirdupois (1 Prussian loth), there are from ·1 to ·12 grammes (= 1·5 to 1·9 grains of caffein). In a cup of tea made from 5 to 6 grammes (= 77 to 92 grains) of tea, about the same amount of caffein is contained.

*As an article of diet*, coffee stimulates the nervous system, and in large doses produces tremors. Caffein given to animals augments reflex action, and may produce tetanus, or peculiar stiffness of muscles. It increases the frequency of the pulse in men, and removes the sensation of commencing fatigue during exercise. It has been said (J. Lehmann and others) to lessen the amount of urea and phosphoric acid, but this is doubtful.‡ It appears, however, to increase the urinary water. The pulmonary carbonic acid is said to be increased (E. Smith). It increases the action of the skin.

In animals (frogs, dogs, and rabbits), caffein produces the following effects, as determined by Aubert and others:—Increased reflex action; a peculiar stiffness of the muscles, sometimes tetanus; no lessening of nervous excitability; an invariable increase in pulse-frequency, and a lessening of the blood-pressure (in dogs). This effect on the circulation is peculiar and complex. Aubert is convinced that the work of the heart is less, in spite of the increased beats; there is not time for perfect contraction, and this lessened power shows itself, he thinks, in the lessened blood-pressure. Aubert considers that the lessened heart-pressure is dependent on a more or less marked paralysis of the nerves passing to the heart from the ganglia; the increased frequency must be dependent either on paralysis of the regulating or excitation of the contractive heart nerves, and of this alternative he adopts the latter. He thinks it uncertain whether coffee owes its dietetic value to the caffein.

Coffee is a most important article of diet for soldiers,§ as not only is it invigorating, without producing subsequent collapse, but the hot infusion is almost equally serviceable against both cold and heat: in the one case, the warmth of the infusion, in the other, the action on the skin, being useful, while in both cases the nervous stimulation is very desirable. Dr Hooker tells us that in the Antarctic expedition the men all preferred coffee to spirits, and this was the case in the Schleswig-Holstein war of 1849.

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* Archiv. für die ges. Phys., band v. p. 589.

† Caffein, theine, and theobromine are the same substance. In the leaves of the Paraguay tea (*Ilex paraguayensis*, the tea is called Maté in Paraguay), which are used to make tea in the Argentine confederation, and throughout the southern part of Brazil, there is also an alkaloid identical with theine. In dietetic properties, Paraguay tea is thought to stand between coffee and Chinese tea, but to be more like coffee. The alkaloid in guarana is also theine, according to Stenhouse.

‡ While Hoppe found a decrease in dogs, Voit found no alteration of urea; and some very careful experiments, made by Dr Squarey of University College, do not confirm Lehmann's observations on men so far as the urea is concerned. Dr Squarey's experiments are far more complete than those of Lehmann; the urea was not affected even by very large quantities of coffee. It would be interesting to examine the urine again after the use of the *Erythroxylon coca*. The late work of M. Moreno of Maiz (Paris 1868), confirms the previous statements of the removal of the sensation of hunger by this substance. The cold infusion increases, he affirms, the arterial tension.

§ The ration, one ounce, is generally too small, and might advantageously be doubled at least. See experiments recorded in "The Issue of a Spirit Ration" (Parkes), Appendix I. p. 39. *et seq.*

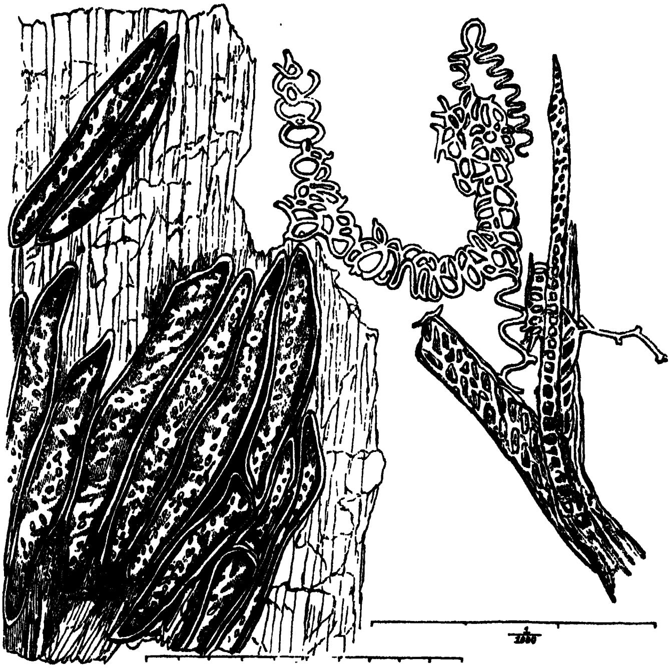

Fig. 63.—Testa of raw Coffee × 170; the right-hand figure shows the double spiral fibres in the raphe of the berry × 500.

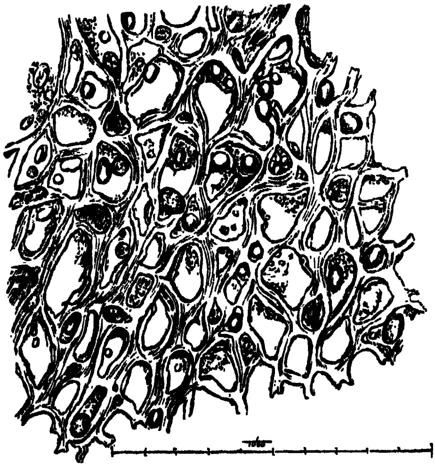

Fig. 64.—Raw Coffee-berry; transverse section × 170.

The experience of Algeria and India (where coffee is coming more and more into use) proves its use in hot climates.

It has been asserted to be protective against malaria. The evidence is not strong, but still is sufficient to authorise its use in malarious districts.

*Making of Coffee.*—Roasted and ground coffee must be served out to troops, as the delicate operation of roasting can never be performed by soldiers. Exposed to the air, the roasted and ground coffee loses its aroma in from two to four months; but if packed in tins it will keep it for several months. The tins should not be too large, so that no more than necessary may be exposed to the air. It has been said that the tin is acted upon, but this does not appear to be the case for some time. The amount should be at least $\frac{6}{10}$ths of an ounce for each person per meal.

The coffee must not be boiled, or the aroma is in part dissipated; but if made with water of 180° or 200°, the coffee only gives up 19 to 25 per cent., whereas it ought to yield 30 to 35 per cent. In order to get the full benefit of the coffee, therefore, after the infusion has been poured off, the grounds should be well boiled in some more water, and the hot decoction poured over fresh coffee, so that it may take up aroma; the coffee thus partially exhausted can be used on the next occasion for boiling.

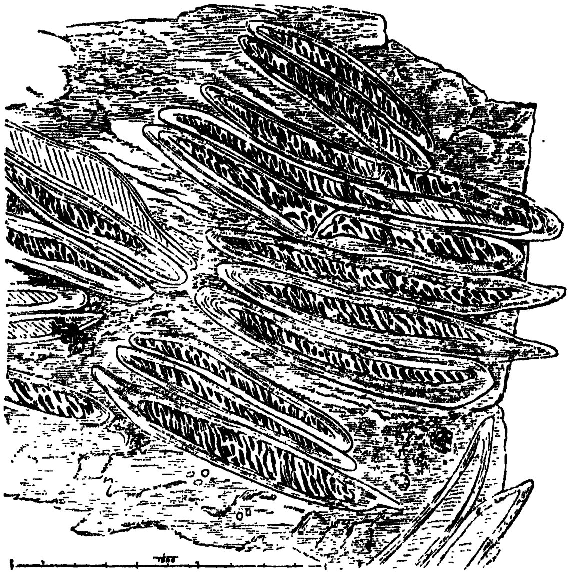

Fig. 65.—Roasted Coffee; the dark cells, containing air, show the spiral fibre.

The infusion of coffee has a specific gravity of about 1008 to 1010; the oil caffein, sugar, dextrin, and mineral matters, are taken up by water.

*Choice of Coffee.*—This is determined entirely by the aroma and taste of the roasted coffee and of the infusion. If the coffee has been damaged (as by sea-water, when the berries are washed in fresh water and redried), there is always a disagreeable taste even after roasting (Chevallier). The berries give up less than usual to water (12 per cent.)*

*Adulterations.*—The microscope detects adulterations with the greatest facility.

The structure of the coffee-berry is shown in the drawings.

The long cells of the testa (figs. 63 and 65) are very marked. The interior of the berry also presents characters which are quite evident; an irregular areolar tissue contains light or dark yellow angular masses and oil globules, which are very different from any adulterations. The little cork-screw-like unrolled spiral fibres are chiefly found in the bottom of the raphe.

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* With regard to the choice of the coffee berry some caution must be used. The best coffee, that of Yemen, originally the Abyssinian berry, is a moderately large full berry (according to Palgrave), the inferior sorts being small and shrivelled. In India the same rule does not seem to hold good, and I have been told by officers of experience that in that country the best coffee is often a shrivelled and uninviting-looking article, whilst the fuller and apparently finer samples are really inferior for use as a beverage. (F. de C.)

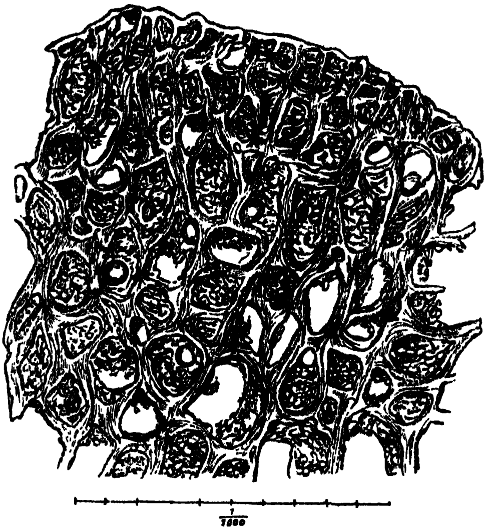

Fig. 66.- Roasted Coffee-berry; transverse section.

The usual adulterations of coffee are roasted chicory;* cereal grains or beans, potatoes, and sugar.

1. Chicory is discovered by its smell; by yielding a darker and denser infusion of a specific gravity of 1018 to 1020; and by its microscopic characters. It also sinks at once in water when roasted, whereas coffee floats for a long time in consequence of the development of gas during roasting, or from the non-absorbent character of the perisperm and hard yellow granules of the cellulose. The microscopic test is the most important, and both the cells and dotted ducts of chicory are quite characteristic, at least nothing like them exists in coffee.† The percentage of ash has been suggested as a means of detection. Coffee yields about 4 per cent., of which four-fifths are soluble in water: chicory yields about 5 per cent., of which only one-third is soluble.

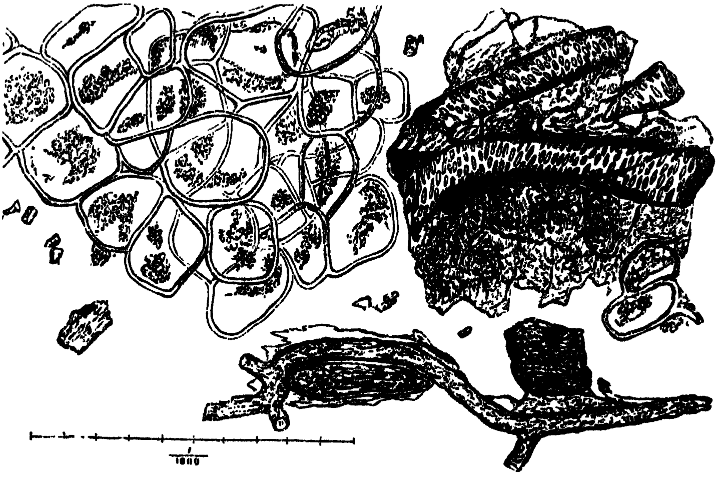

Fig. 67.—Chicory root; cells and dotted ducts.

2. Roasted corn or beans are at once known by the starch-grains, which

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* Chicory is itself adulterated with roasted barley and wheat grain, acorns, mangold-wurzel, saw-dust, and beans and peas.

† Chicory contains a notable amount of sugar (12·14 per cent.), whereas coffee never has more than 1 per cent. Wanklyn has proposed to make this a basis of detection, using the copper test.

frequently preserve the precise character of wheat or barley or beans. (See figures of these grains, p. 227 *et seq.*) Iodine turns them at once blue. The infusion also gives a blue with iodine.

3. Potato starch is also at once detected; there is nothing like it in coffee. (See figure, p. 232.) Sago starch, which is sometimes used, is easily detected.

4. Sugar is detected by solution, and by the copper solution which it reduces, as the kind of sugar is almost always glucose. If caramel or burnt sugar be present, make an infusion, evaporate, dry, and taste; if the extract be brittle, dark coloured, and bitter to the taste, caramel has been added (Hassall).

5. Pereira* has given a long list of adulterations of chicory, and Hassall has also detected mixture with mangold-wurzel, parsnip, carrot, acorn, and saw-dust. The cells of mangold-wurzel are like chicory, but much larger; those of carrot and parsnip are something like chicory, but contain starch cells; the starch-grains of the acorn are round or oval, with a deep culvert depression, or hilum. The infusion of chicory is not turned blue by iodine; when incinerated the ash of chicory should not be less than 5 per cent.

## SUB-SECTION II.—TEA.

The chief kinds of black tea are Souchong, Congou, Oolong, and Pekoe. Bohea is not now found in the market. The chief green teas are Hyson, Hyson-stem, Twankay, Caper, and Gunpowder.

Dry tea contains about 1·8 per cent. of thein; 2·6 of albumen; 9·7 of dextrin; 22 of cellulose; 15 of tannin; 20 of extractives; 5·4 of ash, as well as other matters, such as oil, wax, and resin.

In some good teas the amount of thein is much greater. Péligot found as much as 6·21 per cent. in dry tea. The thein is combined with tannic acid.

Black tea contains from 6 to 10 per cent. of water—more often the latter quantity; green tea about 8 per cent.

The ash consists principally of potash, soda, magnesia, phosphoric acid, chlorine, carbonic acid, iron, and silica.† There is rather more tannic acid, and more thein and ætherial oil, in green than black tea, and less cellulose: otherwise the composition is much the same (Mulder).

| | | |
|---|---|---|
| Black tea yields to boiling water, . . | | 29–45 per cent. |
| | As a mean, . | 38 „ |
| Green,‡ . . . . . . . | | 40–48 „ |
| | As a mean, . | 43 „ |

About $\frac{6}{7}$ths of the soluble matters are taken up by the first infusion with hot water.§

If water contain much lime or iron, it will not make good tea; in each case the water should be well boiled with a little carbonate of soda for 15 or 20 minutes, and then poured on the leaves.

In the infusion are found dextrin, glucose, tannin, and thein. About 47 per cent. of the nitrogenous substances pass into the infusion, and 53 per cent. remain undissolved. If soda is added, a still greater amount is given to water.

The green tea (now little sold) is either natural or coloured (faced) with indigo, Prussian blue, clay, carbonate and acetate of copper, curcuma, gypsum, and chalk.

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* Materia Medica, vol. ii. p. 1578 (1863).

† The Society of Public Analysts have adopted 8 per cent. of ash as the maximum of perfectly dry tea. The amount in ordinary tea is about 5 to 6 per cent., of which about 3 per cent. is soluble. The ash of *spent* tea is only about 3 per cent., of which 0·5 is soluble.

‡ There appears now to be very little green tea in the market, since it has been decided that "facing" is an adulteration.

§ The Society of Public Analysts have adopted 30 per cent. as the minimum extract in genuine tea; Wanklyn takes 32, and certainly good genuine tea generally yields this at least.

Scraping the tea-leaves and microscopic examination at once detect the shining blue particles of indigo and Prussian blue; and the addition of an acid indicates which is indigo.* Copper is at once detected by solution in an acid and addition of ammonia. Letheby mentions that black lead is used to give a bloom to black teas.

*As an Article of Diet.*—Tea seems to have a decidedly stimulative and restorative action on the nervous system, which is perhaps aided by the warmth of the infusion. No depression follows this. The pulse is a little quickened. The amount of pulmonary carbonic acid is, according to E. Smith, increased.† The action of the skin is increased; that of the bowels lessened. The kidney excretion is little affected; perhaps the urea is a little lessened, but this is uncertain.‡

As an article of diet for soldiers, tea is most useful. The hot infusion, like that of coffee, is potent both against heat and cold; is most useful in great fatigue, especially in hot climates (Ranald Martin); and also has a great purifying effect on water. Tea is so light, is so easily carried, and the infusion is so readily made, that it should form the drink *par excellence* of the soldier on service. There is also a belief that it lessens the suceptibility to malaria, but the evidence on this point is imperfect.

*Choice of Tea.*—The tea should not be too much broken up, or mixed up with dirt. Spread out, the leaves should not be all large, thick, dark, and old, but some should be small and young. There will always be in the best tea a good deal of stalk and some remains of the flower. In old tea much of the ætherial oil evaporates, and the aroma is less marked.

The infusion should be fragrant to smell, not harsh and bitter to taste, and not too dark. The buyers of tea seem especially to depend on the smell and taste of the infusion.

*Structure of the Tea Leaf.*—The border is serrated nearly, but not quite to the stalk; the primary veins run out from the midrib nearly to the border, and then turn in, so that a distinct space is left between them and the border. The leaf may vary in point of size and shape, being sometimes broader, and sometimes long and narrow. The appearance under the microscope of the upper and under surfaces is seen in the drawing. The border and the primary venation distinguish it from all leaves.§ The leaves which it is said have been mixed with or substituted for tea in this country are the willow, sloe, oak, Valonia oak, plane, beech, elm, poplar, hawthorn, and chestnut; and in China, *Chloranthus inconspicuus* and *Camellia Sasanqua* are said to be used.

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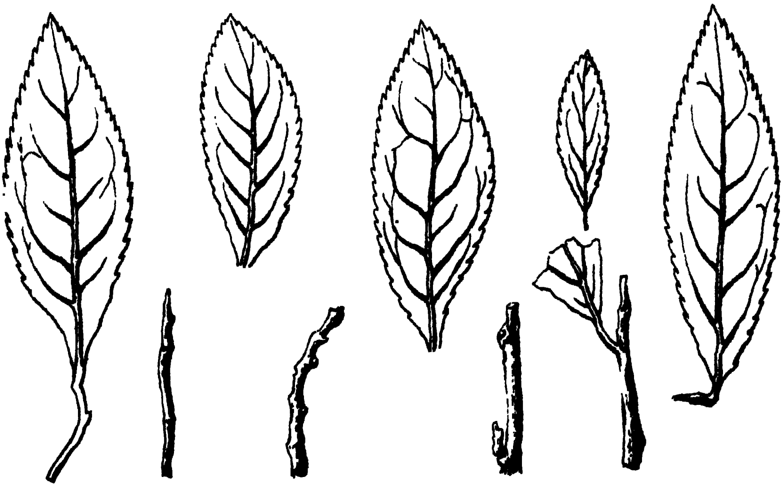
* The brick tea of the Tartars consists of old tea leaves, mixed with the leaves and stems of *Rhamnus theèzans*, *Rhododendron*, *Chrysanthemum*, *Rosa canina*, and other plants, mixed with ox's or sheep's blood. It is much used to purify water.

† Phil. Transactions, 1859.

‡ The evidence with respect to the urine is very contradictory; but, on the whole, the action seems to be inconsiderable. Dr Edward Smith considers that, "tea promotes all vital actions, and increases the action of the skin." It is, perhaps, impossible at present to express its action in so succinct a form.

§ The structure of the serrature is rather peculiar, showing an apparently abortive leaf-bud just within the point. This organ can be seen distinctly with an ordinary pocket lens, and consists of a cylindrical basal portion and a more or less cone-shaped apical part. From the reticulated body of the venation, a distinct little funiculus may be traced into each of the minute bud-like bodies which are situated just *within* the tip of the serrature. This latter particular is of importance, for, as might be expected, somewhat similar appendages may be found in other serrated leaves, but in all cases hitherto examined by us, they occur *at* instead of *within* the point of the serratures. No notice appears to have been taken of this fact by structural botanists; but Dr Macdonald, who first called attention to it, refers the bodies themselves to the category of marginal buds. (F. de C.)



Leaves and stalks of best Tea brought from China (1861) by private hand natural size
Generally in commercial Tea the leaves are much larger & thicker, & often are cut transversely into two or three parts Some stalks & remains of flowers are found in all Tea even the best

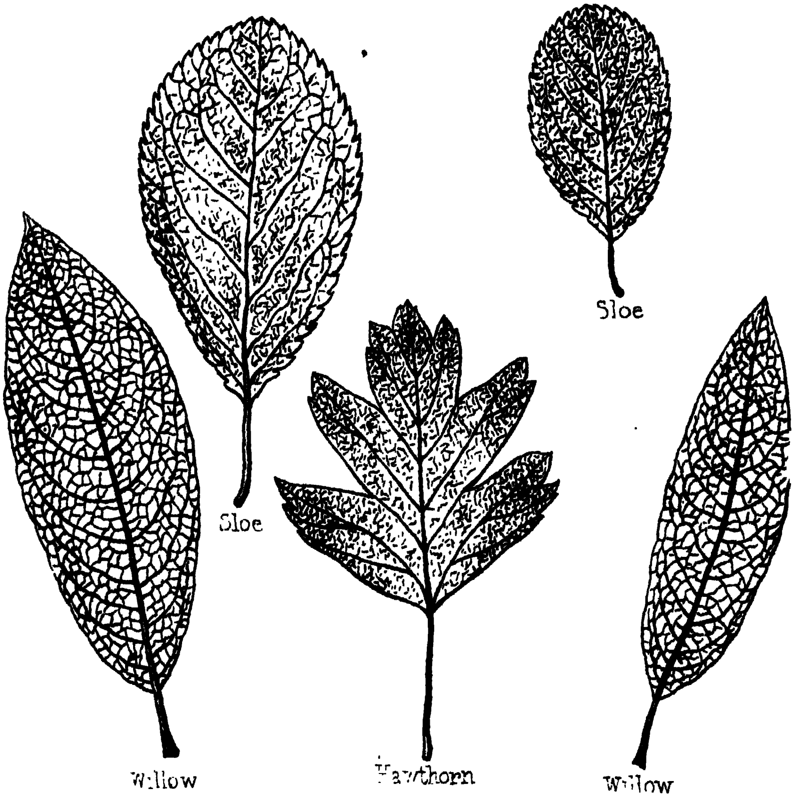
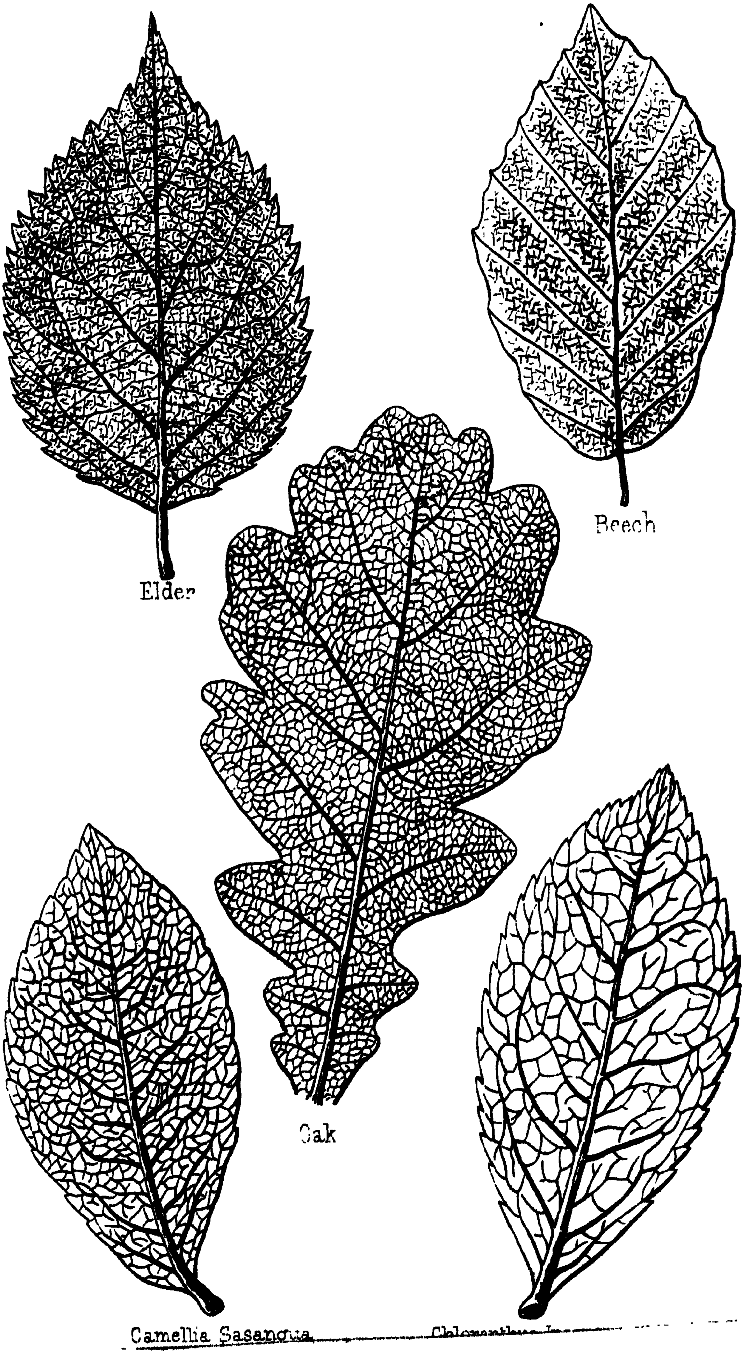


Plate VIII



Of these the willow and the sloe are the only leaves which at all resemble tea leaves. The willow is more irregularly, and the sloe is much less perfectly and uniformly serrated.

To examine the leaves, make an infusion, and then spread out a number of leaves; if a leaf be placed on a glass slide, and covered with a thin glass, and then held up to the light, the border and venation can usually be well seen.

The leaves of the Valonia, if used, are at once detected by acicular crystals being found under the microscope.

Sometimes exhausted tea leaves are mixed with catechu or with a coarse powder of a reddish-brown colour, consisting chiefly of powdered catechu, and called "La Veno Beno." Gum and starch are added, the leaves being steeped in a strong solution of gum, which, in drying, contracts them. The want of aroma, and the collection at the bottom of the infusion of powdered catechu, or the detection of particles of catechu, will at once indicate this falsification, which is, however, very uncommon. Sand and magnetic oxide of iron are added by the Chinese. At first the latter was mistaken for iron filings, and when it was proved to be really magnetic oxide it was suggested that it came accidentally from the soil where the tea was cultivated. Hassall, however, gives good reasons for its being a wilful addition.*

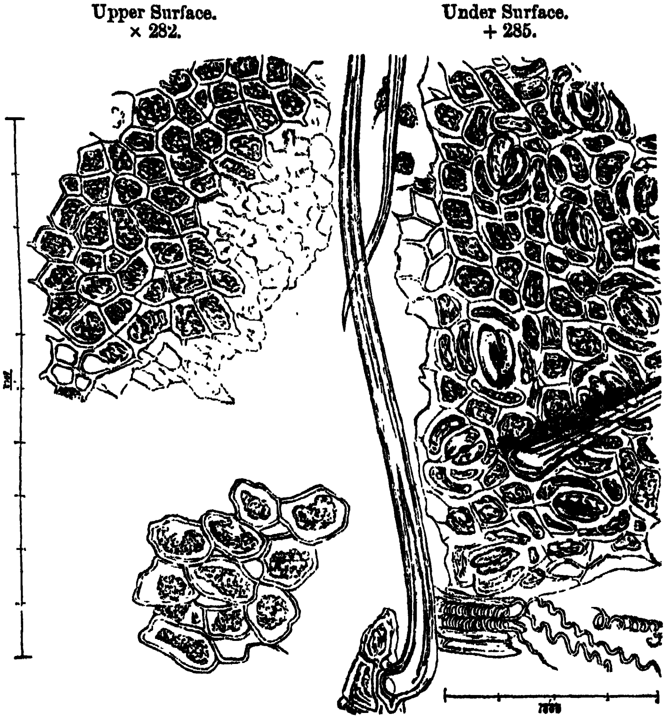


Fig. 68.—Dried Black Tea Leaf.

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* I have found minute quantities in two instances in tea supplied to Netley Hospital; in one the ash was 6·054 per cent.; in the other, 6·220. Hassall states that he has never found it except in tea that has been undoubtedly adulterated and yielded a very much greater amount of ash. (F. de C.)

### *Extraction of Thein.*

Occasionally it may be desired to determine the quantity of thein. Take 10 grammes of tea, exhaust with boiling water, and add solution of subacetate of lead; filter; pass hydrosulphuric acid, to get rid of excess of lead; filter; evaporate to small bulk, and add a little ammonia; add more water, decolorise with animal charcoal, and evaporate slowly to small bulk. White feathery crystals of thein form, which should be collected on filtering paper, dried at a very low heat, and weighed.

### *Determination of Tannin.*

Make an infusion, and add solution of gelatine; collect precipitate, dry and weigh—100 parts = 40 of tannin (Marcet).

### *Examination of Tea.*

Judge of the aroma of the dry tea and infusion; taste infusion; spread out leaves and see their characters; collect anything like mineral powder, and examine under microscope. The microscope will also show if the tea has deteriorated by keeping; sometimes acari, fungi, and bacteria may be found.

To make the infusion, take 10 grammes of tea and infuse in 500 C.C. of *boiling* distilled or rain water.* Let it stand five or six minutes before smelling and tasting it. Exhaust the leaves by boiling with successive portions of water, until no colour is given up to the water. Measure the total amount of the infusion; take 100 C.C. and dry it in a water-bath† and weigh. Calculate out the percentge.

*Example.*—The total quantity of the infusion from 10 grammes of tea was 1890 C.C.; 100 C.C. taken and dried yielded 0·21 of extract; then $\frac{1890}{100} \times 0{\cdot}21 = 3{\cdot}969$ of extract in 10 grammes; this multiplied by $10 = 39{\cdot}69$ per cent.

The exhausted leaves may also be dried and weighed, the loss representing the amount of extract, which ought to correspond with the amount obtained directly.

The ash should also be determined; 5 or 10 grammes are to be incinerated; the ash is generally grey, sometimes slightly greenish. Any excess above 6 per cent. is suspicious; if above 8 per cent. on the *perfectly dry tea*, adulteration is certain. About one-half of the ash is soluble in water; the solution is often (but not always) pink, from the presence of manganese. The amount and character of the ash form good means of detecting the use of exhausted leaves.

The acidity of the infusion, and the amount of tannin and thein may also be determined; as also the chlorine, alkalinity, and iron of the ash. The best tests of the *quality* of the tea are the aroma and the physical characters.

## SUB-SECTION III.—COCOA.

*Composition.*—Although the theobromin of cocoa is now known to be identical with thein and caffein, the composition of cocoa removes it widely from tea and coffee. The quantity of fat is large; it varies even in the same sort of cocoa, but is usually from 45 to 49 per cent.;* the theobromin is 1·2 to 1·5 per cent.; the protein substances 13 to 18 per cent. The ash contains a large quantity of phosphate of potash.

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* The dealers usually take as much tea as is equal in weight to a new sixpence for the infusion. This is equal to about 3 grammes; it is dissolved in a cupful of water, about 5 ounces or 140 C.C.

† Mr Wanklyn suggests a simple form of water-bath; an ordinary tin oil-can about three-parts full of water; this is boiled over a lamp, and the dish with infusion to be dried held over the narrow mouth in the ring of a retort stand. The drying is soon completed in the steam.

*As an Article of Diet.*—The large quantity of fat and albuminoid substance makes it a very nourishing article of diet; and it is therefore useful in weak states of the system, and for healthy men under circumstances of great exertion. It has been even compared to milk. In South America cocoa and maize cakes are used by travellers; and the large amount of agreeable nourishment in small bulk enables several days' supplies to be easily carried (Humboldt).

By roasting, the starch is changed into dextrin; the amount of margaric acid increases, and an empyreumatic aromatic substance is formed.

The changes depend on the amount of roasting; the lighter-coloured nuts contain more unchanged fat, and less aroma; the strongly roasted and dark cocoas have more aroma and bitterness.

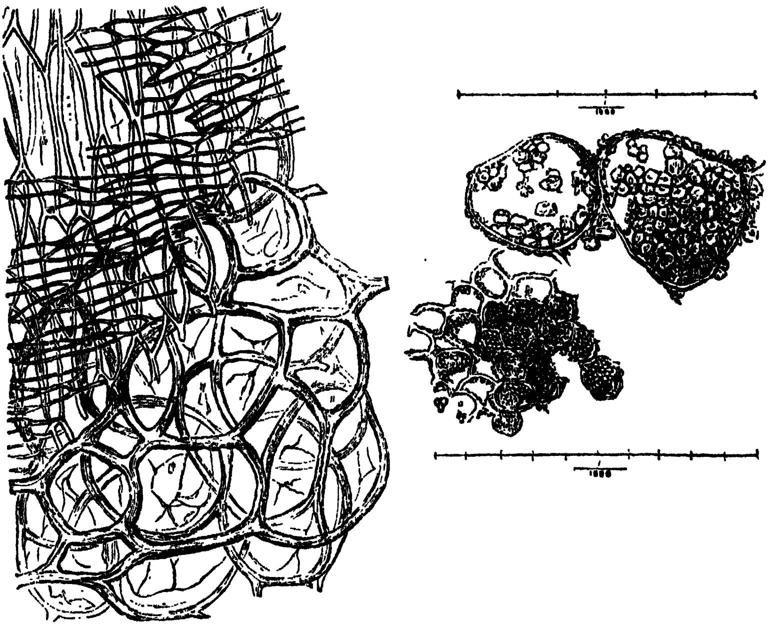

Fig. 69.—Cocoa, Outer Coat × 190.

*Choice and Adulterations.*—In commerce, cereal grains, starches, arrowroot, sago, or potato starch and sugar, are very commonly mixed with cocoa; and some of the so-called homœopathic cocoas are rightly named, for the amount of cocoa is very small. Brick-dust and peroxide of iron are sometimes used (Normandy).† The structure of the cocoa is very marked.

The starch-grains of cocoa are small, and embedded usually in the cells.

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* The Society of Public Analysts have adopted 20 per cent of Cocoa butter as the minimum admissible.

† Hassall examined 54 samples; 8 were genuine, 43 contained sugar, and 46 starch; 39 out of 68 samples contained earthy colouring matter, as reddle, Venetian red, and umber (On Adulteration, p. 169).

The presence of starch-grains of cereals, arrowroot, sago, or other kinds of starch, is at once detected by the microscope (see figures *ante* of these starches). Sugar can be detected by the taste, and by solution. Mineral substances are best detected by incineration, digesting in an acid, and testing for iron, lead, &c.

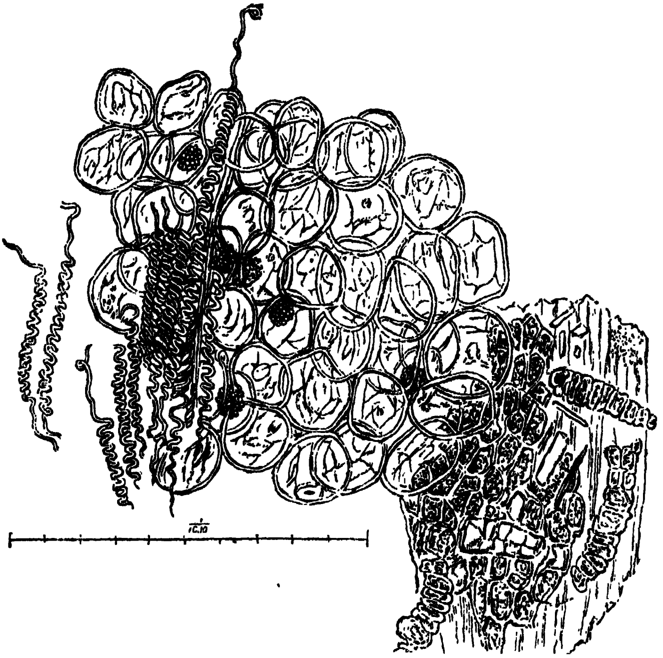

Fig. 70.—Cocoa, Under Parts, Middle Coat × 190.

# SECTION III.

## CONDIMENTS.

### Sub-Section I.—Vinegar.

*As an Article of Diet.*—Robert Jackson was of opinion that the use of vinegar was too restricted in the army. This opinion he appears to have formed from considering the great use of vinegar made by the Romans. Whatever may have been the source of the opinion, there is no doubt of its correctness. Acetic acid plays that double part in the body which seems so important, of first an acid of a neutral salt, and then, in the form of carbonic acid, as the acid of an alkaline salt. But this valuable dietetic quality is partly counter-balanced in English vinegar by the unfortunate circumstance that sulphuric acid ($\frac{1}{1000}$th part in weight) is allowed to be added to vinegar, and thus a strong acid is taken into the body, which is not only not useful in nutrition, but which is hurtful, from the tendency to form insoluble salts of lime. As the addition of sulphuric acid is not necessary,* and, indeed, is not permitted on the Continent, it is to be hoped the legislature will soon alter system which has the effect only of injuring an important article of diet. The amount of vinegar which may be used may be from one to several ounces. On marches, the Romans mixed it with water as a beverage.

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* The absence of *Anguillula Aceti* has been by some attributed to the use of sulphuric acid. See Micrographic Dictionary, article *Anguillula*. In a sample I examined, which swarmed with anguillulæ, there was only a trace of sulphuric acid. (F. de C.)

*Examination of Vinegar.*—Several kinds of vinegar are in the market, known by the Nos. 16, 18, 20, 22, 24. Nos. 22 and 24 are the best, and contain about 5 per cent. of pure acetic acid. The weakest kinds contain less than 3 per cent. The Society of Public Analysts have adopted 3 per cent. as the minimum admissible.

*Quality.*—1. Take specific gravity; of the best, = 1022; of the worst, = 1015. If below this, water has been added.

2. Determine acidity of 10 C.C. with the alkaline solution (see Beer). It is generally best to dilute the vinegar ten times with distilled water, and to take 10 C.C. of the diluted vinegar. Multiply the C.C. of alkaline solution used by 0·6, the result is acetic acid per cent.

*Example.*—10 C.C. of diluted vinegar took 8 C.C. of alkaline solution: 8 0·6 = 4·8 per cent. of acetic acid.

The acidity of English vinegar is chiefly caused by acetic and sulphuric acids, but it is usually calculated at once as glacial acetic acid. If it falls below 3 per cent.,* water has probably been added. (The lowest noted by Hassall in 33 samples was 2·29.)

If the specific gravity be low, and the acidity high, excess of sulphuric acid may have been added.

If the alkaline solution cannot be prepared, the acidity must be determined with dried or crystallised sodium carbonate. Weigh 10 grammes of dried sodium carbonate, and add portions carefully to a weighed quantity of vinegar (10 grammes), till it is neutralised; then weigh the remaining sodium carbonate, and calculate according to the atomic weights ($53 : 60 = a : x$), or multiply the quantity used by 1·132; the result is the amount of glacial acetic acid in the quantity of vinegar experimented upon.

In adding sodium carbonate to *wine* vinegar, the colour becomes dark and inky. Ammonia also gives a purplish precipitate in *wine*, but not in malt vinegar.

3. If excess of sulphuric acid be suspected, it must be determined by baryta; this requires care, as sulphates may be introduced in the water. Hydrochloric acid and barium chloride are added; the sulphate of barium collected, dried, weighed, and multiplied by ·34305.

*Adulterations.*—Water; sulphuric acid in excess (see *ante*);† hydrochloric acid (uncommon); or common salt (detected by nitrate of silver and dilute nitric acid); pyroligneous acid (distil and re-distil the distillate, the residue will have the smell of pyroligneous acid); lead; copper from vessels (evaporate to dryness, incinerate, dissolve in weak nitric acid, divide into two parts, pass $SH_2$ through one, and test for copper in the other by ammonia, or by a piece of iron wire); corrosive sublimate (pass $SH_2$ through, collect precipitate); capsicum, pellitory, or other pungent substances (evaporate nearly to dryness, and dissolve in boiling alcohol, evaporate to syrup, taste; burnt sugar gives a bitter taste and a dark colour to the syrup).

The presence of copper in the vinegar used for pickles may be easily detected by simply inserting the bright blade of a steel knife.

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* Hassall, says 3·5 per cent.

† The presence of sulphuric acid may be detected qualitatively, by adding a few drops of the inegar to a piece of cane sugar, and evaporating on the water-bath. The solution becomes black in proportion to the mineral acid present. (Hassall).

### SUB-SECTION II.—MUSTARD.

Good mustard is known by the sharp acrid smell and taste. It is adulterated with turmeric (detected by microscope and liquor potassæ), wheat or barley starch (detected by microscope and iodine), and linseed (detected

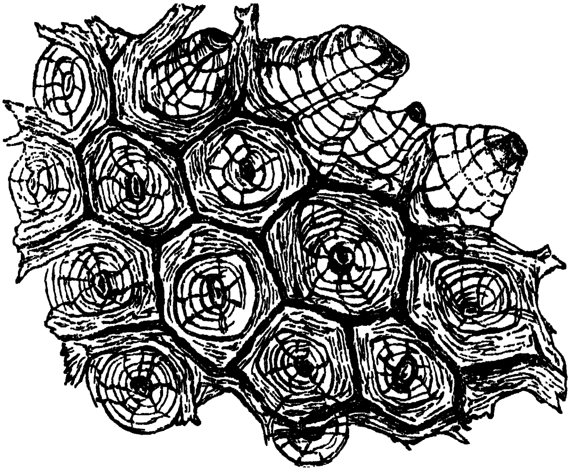

Fig 71.—White Mustard Seed.—Cuticle consisting of a perforated cellular epiderm and mucilage cells, some by expansion escaping through the cuticular openings after being placed in water.

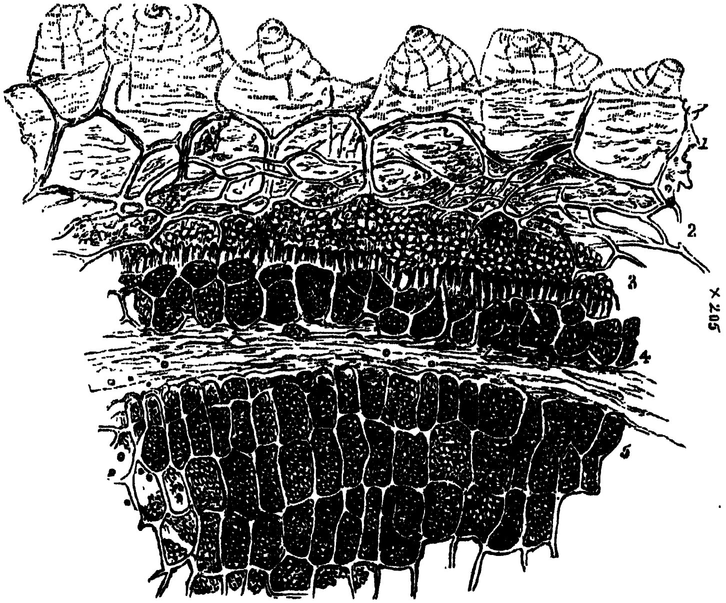

Fig. 72.—White Mustard Seed.—1. Outer coat, cuticle mucilage cells; 2. Fibrous reticular; . Small angular cells; 4. Large cells and very delicate membrane; 5. Interior of seed with a few minute oil globules.

by microscope). Many samples of mustard are still mixed with turmeric and starch of some kind, but this has very much lessened since the passing of the Adulteration Act. Clay and plaster of Paris are sometimes added, and cayenne is added to bring up the sharpness, if much flour is used.

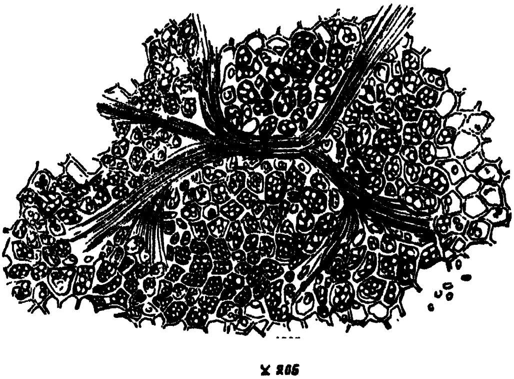

Fig. 73.—White Mustard Seed,—Central part, × 205.

The microscopic characters of mustard are well marked. The outer coat of the white mustard consists of a stratum of hexagonal cells, perforated in the centre, and other cells which occupy the centre portion of the hexagonal cells,

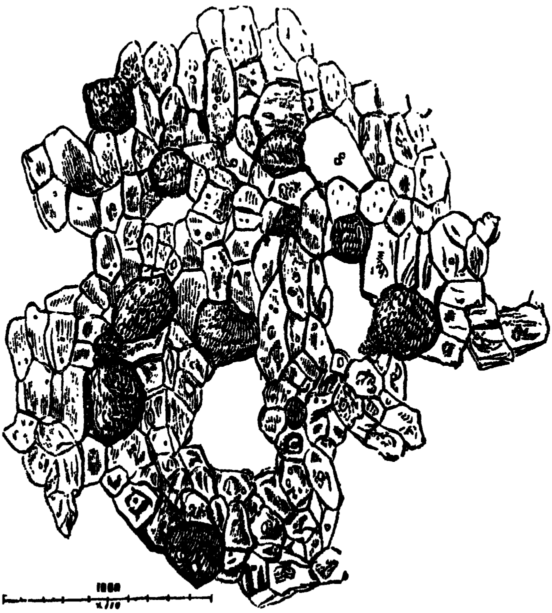

Fig. 74.—Section of Black Pepper Berry (central portion).

and escape through the opening when swollen from imbibition of water; these cells are believed to contain the mucilage which is obtained when mustard is placed in water. There are two internal coats made up of small angular cells;

the structure of the seed consists of numerous cells containing oil, but no starch. The black mustard has the same characters, without the infundibuliform cells.

### SUB-SECTION III.—PEPPER.

Pepper is adulterated with linseed, mustard husks, wheat and pea-flour, rape cake, and ground rice. The microscope at once detects these adulterations.

The microscopic characters of pepper are rather complicated; there is a husk composed of four or five layers of cells and a central part. The cortex has externally elongated cells, placed vertically, and provided with a central cavity, from which lines radiate towards the circumference; then come some strata of angular cells, which, towards the interior, are larger, and filled with oil. The third layer is composed of woody fibre and spiral cells. The fourth layer is made up of large cells, which towards the interior become smaller and of a deep red colour; they contain most of the essential oil of the pepper. The central part of the berry is composed of large angular cells, about twice as long as broad. Steeped in water, some of these cells become yellow, others remain colourless. It has been supposed that the yellow cells contain piperine as they give the same reactions as piperine does; the tint, namely, is deepened by alcohol and nitric acid, and sulphuric acid applied to a dry section causes a reddish hue (Hassall).

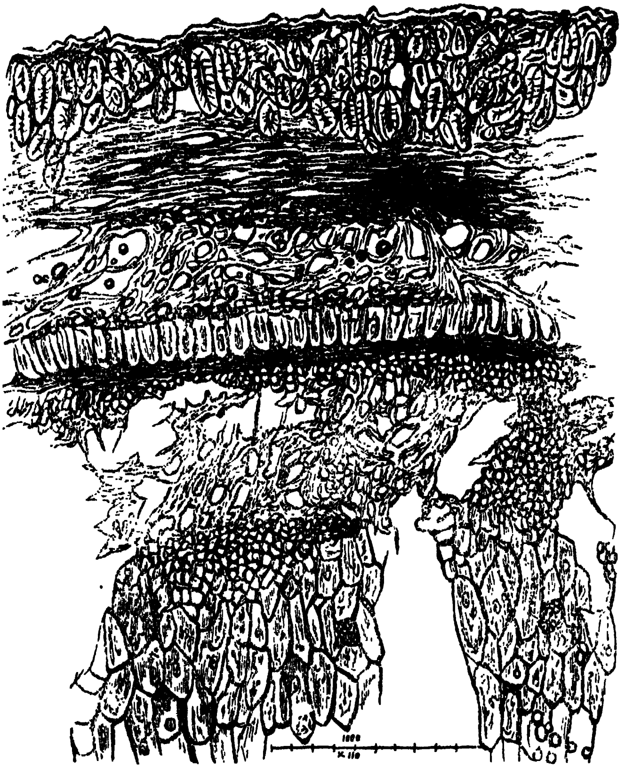

Fig. 75.—Transverse Section of Black Pepper Berry.

White pepper is the central part of the seed, but some small particles of ortex are usually mixed with it. It is composed of cells containing very mall starch-grains. Hassall says that the central white cells are so hard they nay be mistaken for particles of sand. A little care would avoid this. The tarch-grains are easily detected, however small, by iodine.

Pepper dust is merely the sweepings of the warehouses. Rape or linseed ake, cayenne and mustard husks, are mixed with pepper dust, and it is then old as pepper.

### SUB-SECTION IV.—SALT.

The goodness of salt is known by its whiteness, fine crystalline character, lryness, complete and clear solution in water. The coarser kinds, containing ften chloride of magnesium, and perhaps lime salts, are darker coloured, more r less deliquescent, and either not thoroughly crystallised or in too large rystals.

## SECTION IV.

## LEMON AND LIME JUICE.

These juices contain free acids in large quantities, chiefly citric, and a little nalic acid, sugar, vegetable albumen, and mucus.

The expressed juice of the ripe fruit of the *Citrus Limonum*, as ordered by he British Pharmacopœia, is said to have a specific gravity of 1·039, and to ontain on an average 32·5 grains of citric acid in one fluid ounce.* The resh juice of the lime (*Citrus Limetta*, or *Citrus acida*) has a rather less pecific gravity (1·037), and contains less acid (32·22 grains per ounce).†

The late very important Merchant Shipping Act,‡ which regulates the issue f lemon juice on board merchant vessels, does not define the strength; but it as been stated by Mr Stoddart§ that the Board of Trade standard is a specific ravity of 1030 without spirit, and 30 grains of citric acid per ounce. It ccasionally is as high as 1050.

As found in commerce, for merchant shipping, or used in the Royal Navy, he lime or lemon juice is chiefly prepared in Sicily or the West Indies; it is nixed with spirit (usually brandy or whisky, which gives it a slightly reenish-yellow hue), and olive oil is poured on the top.

Sugar is added to it when issued, to make it more agreeable to taste, in the roportion of half its weight. Lemon juice is usually issued in bottles conaining three to four pints, not quite filled, and is covered with a layer of live oil. About 1 ounce of brandy is added to each 10 ounces of juice. Sometimes the juice is boiled, and no brandy is added; the former kind keeps est (Armstrong). Both are equal in anti-scorbutic power (Armstrong). Good emon juice will keep for some years, at least three years (Armstrong); bad uice soon becomes turbid, and then stringy and mucilaginous, and the citric nd malic acids decompose, glucose and carbonic acid being formed. Some urbidity and precipitate do not, however, destroy its powers.

As found in the market, it is frequently mixed with water, and sometimes with other acids. In 20 samples examined in 1868 by Mr Stoddart 7 were genuine, 5 were watered, and 8 were artificial; tartaric acid being present in one, and sulphuric acid in another sample.

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* Mr Stoddart (Pharm. Jour. Oct. 1868) points out that the specific gravity is too high for he quantity of acid stated; there may, however, be other ingredients. He gives himself the pecific gravity as 1·040 to 1·045, and the citric acid as 39 to 46 grains per ounce (citric acid $_8H_8O_7$). Mr Stoddart mentioned that when lemons are kept the citric acid decomposes, and lucose and carbonic acid arises. But yet citric acid is made from damaged fruit.

† Stoddart, *op. cit.* p. 205.

‡ The Merchant Shipping Act, 1867. Mr Harry Leach, who superintends the part of the Act elating to lemon juice, has arranged a very good scheme of examination, which is being carried ut by himself and by inspectors at the various ports.

§ Pharm. Jour. Oct. 1868, p. 204.

I have examined two good specimens of the Royal Navy lemon juice from Sicily, with the following results :—When evaporated carefully down, after separation of the oil, it formed a brownish fragrant mass, which was dried with some difficulty, but was afterwards completely soluble in water. (If the operation is carried too far the extract decomposes, and then forms, according to Mr Stoddart, acetone, carbonic acid, and carbonic oxide and pyrocitric acid.) The look and smell of this extract were very characteristic of true lemon juice. The amount in my two samples was 7·186 and 7·1828 per cent. (Mr Stoddart's experiments give a rather less amount, viz., 6·17). When incinerated an alkaline whitish-grey ash was left; and if the alkalinity was neutralised by a standard acid, it corresponded to ·15 grains of citric acid per cent. The ash was ·52 and ·53 per cent. respectively, and of this ·38 were soluble salts; the potash was ·12 per cent., or just ½ grain per ounce, and the phosphoric acid was ·008 per cent, or ·035 grains per ounce.[*] The total acidity (= citric acid $C_6H_8O_7$) was 4·61 and 5·36 per cent., or on an average nearly 22 grains of citric acid ($C_6H_8O_7$) per ounce.[†]

This was below the Board of Trade's standard. The alcohol was 5 per cent., corresponding to 10 per cent. of brandy added.

In the examination the points which seem to me of consequence, in addition to the determination of the free acidity, are the fragrancy of the extract and the alkalinity of the ash, proving the existence of some alkaline citrate. The latter could, however, be imitated, but the fragrancy cannot be so.

### *Examination of Lemon Juice.*

1. Pour into a glass, and mark physical characters; turbidity, precipitate, stringiness, &c. The taste should be pleasant, acid, but not bitter. Add lime water, and boil; if free citric acid is present, a large precipitate of calcium citrate is formed, which redissolves as the solution cools. Evaporate very carefully to extract, to test the fragrancy, &c.

2. Take the specific gravity, remembering that spirit is present; then, if necessary, evaporate to one-half to drive off alcohol, dilute to former amount, and take specific gravity at 60° Fahr.

3. Determine acidity by alkaline solution as given at page 279. Express the acidity as citric acid ($C_6H_8O_7$); 1 C.C. of the alkaline solution = ·0064 of citric acid. As the acidity is considerable, the best way is to take 10 C.C. of the juice, add 90 C.C. of water, and take 10 C.C. of the dilute fluid, which

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[*] The quantity of potash agrees closely with Mr Stoddart's statement, who found ·3 grains per ounce. Witt's analyses give from ·2 to ·5 per cent. of ash, of which 44·3 per cent. was potash, so that if the ash was ·5, the potash would be ·21 per cent., or ·9 grains in 1 ounce. It is, therefore, certain that the utility of lemon juice is not connected with the potash. So also, if my analyses are right for all samples, the opinion that the phosphoric acid is of consequence must be given up, as it is in such very small amount. Witt found the phosphoric anhydride rather more, viz., ·015 to ·038 per cent.

Mr M. F. Anderson (of Coventry) suggests that the value of citric acid (or lime juice) *is as* a means of rendering the phosphates of the food soluble and consequently assimilable; were this so, the mineral acids ought to be at least partially antiscorbutic, of which there is no evidence. (F. de C.)

[†] The lime-juice used in the Arctic Expedition, 1875–76, gave on analysis 27 grains of citric per ounce as issued, that is, after being fortified with about 15 per cent. of proof spirit. Before fortifying it contained 32 grains. (See analyses by Professor Attfield and Mr Bell, Report of Committee on Scurvy, pages xliii. and li.). Samples analysed at Netley showed a specific gravity of 1023 as issued, and 1035·7 after driving off the alcohol; the extract was about 8¼ per cent. The unfortified juice froze at 25° F., the fortified remained liquid down to 15° F. Prolonged freezing at a temperature of nearly 0° F. produced no change in the character or amount of the constituents.

will give the acidity of 1 C.C. of the undiluted juice. If the number of C.C. used for the diluted juice is multiplied by 2·8 it gives the acidity in grains per ounce.

4. Test for adulteration, viz.—

(*a*) *Tartaric Acid.*—Dilute and filter, if the lime juice be turbid; add a little solution of acetate of potash; stir well, without touching the sides of the glass, and leave for twenty-four hours; if tartaric acid be present the bitartrate of potash will fall.

(*b*) *Sulphuric Acid.*—Add barium chloride after filtration, if necessary; if any precipitate falls, add a little water and a few drops of dilute hydrochloric acid to dissolve the barium citrate, which sometimes causes a turbidity.

(*c*) *Hydrochloric Acid.*—Test with silver nitrate and a few drops of dilute nitric acid.

(*d*) *Nitric Acid.*—This is an uncommon adulteration; the iron or brucine test can be used, as in the case of water.

### *Factitious Lemon Juice.*

It is not easy to distinguish well-made factitious lemon juice; about 552 grains of crystallised citric acid are dissolved in a wine pint of water, which is flavoured with essence of lemon dissolved in spirits. This corresponds to about 19 or 20 grains of dry citric acid per ounce. The flavour is not, however, like that of the real juice, and the taste is sharper. Evaporation detects the falsification.

### *Use of Lemon Juice.*

In military transports, the daily issue of one ounce of lemon juice per head is commenced when the troops have been ten days at sea, and by the Merchant Shipping Act (1867) the same rule is ordered, except when the ship is in harbour, and fresh vegetables can be procured. It is mixed with sugar.*

If dried vegetables can be procured, half the amount of juice will perhaps do.

In campaigns, when vegetables are deficient, the same rules should be enforced. On many foreign stations, where dysentery takes a scorbutic type (as formerly in Jamaica, and even of late years in China), lemon juice should be regularly issued.

### *Substitutes for Lemon Juice.*

Citric acid is the best, or citrate of potash; then perhaps vinegar, though this is inferior, and lowest of all is nitrate of potash.† The tartrates, lactates, and acetates of the alkalies may all be used, but I am not aware of any good experiments on their relative anti-scorbutic powers. If milk is procurable, it may be allowed to become acid, and the acid then neutralised with an alkali. The fresh juices of many plants, especially species of cacti, can be used, the plant being crushed and steeped in water; and in case neither vegetables, lemon juice, nor any of the substitutes can be procured, we ought not to omit the trial of such plants of this kind as may be obtainable.

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* My friend, Mr Harry Leach, has kindly given me the following memorandum on the action of the Merchant Shipping Act:—This Act (commonly called the Duke of Richmond's Act) makes special provisions for the quantity and quality of lime juice and lemon juice supplied to the mercantile marine, for the use of the crews of ships at sea. One ounce is furnished each day to every member of the crew after the ship has been at sea ten days, and directions are given in the authorised Ship Captain's Medical Guide that it is to be mixed with sugar and water before serving out, in the proportion of an ounce of juice to an ounce of sugar and about half a pint of water, which mixture is to be handed over to the crew every day between twelve and one o'clock, *i.e.*, at the ordinary dinner hour. Since this Act came into operation, it is ascertained, by the statistics of the Seamen's Hospital, that scurvy has diminished by more than 70 per cent. in the merchant ships of this country, and that hence, even in the Seamen's Hospital, severe cases of this disease are comparatively rare. The juice is examined, in the first instance, at the laboratory of the Inland Revenue as to specific gravity, amount of citric acid, and extractive matter, as well as absence of sulphuric or other cheap acids. It is then mixed in bond, under the direction of customs' officers, with 10 per cent. of rum, brandy, gin, whisky, or Hollands, and kept in bond until required for shipment.

† On this point see Bryson's paper in the Medical Times and Gazette, 1850. I may also refer to a review on scurvy, which I contributed to the British and Foreign Medical Chirurgical Review," in October 1848, for evidence on the point.

# CHAPTER VIII.

# SOILS.

## TOPOGRAPHICAL REPORTS AND CHOICE OF SITES.

The term soil is used here in a large sense, to express all the portion of the crust of the earth which by any property or condition can affect health. The subdivision into surface soil and subsoil is often very useful; and these terms need no definition.

## SECTION I.

## CONDITION OF SOIL AFFECTING HEALTH.

Soil consists of mineral, vegetable, and often animal substances, in the interstices of which are also air and often water.

In reviewing the conditions which affect health it will be convenient to commence with the air and the water in soils.

### Sub-Section I.—The Air in the Soil.

The hardest rocks alone are perfectly free from air; the greater number even of dense rocks, and all the softer rocks, and the loose soils covering them, contain air. The amount is in loose sands often 40 or 50 per cent.; in soft sandstones, 20 to 40 per cent. The loose soil turned up in agricultural operations may contain as much as 2 to 10 times its own volume of air.

*The nature of the air* in soils has not been perfectly determined; it is mostly very rich in carbonic acid, is very moist, and probably contains effluvia and organic substances, derived from the animal or vegetable constituents, but which have not been properly examined. Occasionally it contains carburetted hydrogen, and in moist soils, when the water contains sulphates, a little sulphuretted hydrogen may be found. It has been recently examined by Nichols* in America, Fodor† in Buda-Pesth, and Lewis and Cunningham‡ in Calcutta. Nichols made his experiments in the Back-bay lands of Boston, Massachusetts, land made by throwing gravel upon sea mud. His first series of experiments was upon air drawn from depths of 3¾ to 5½ feet. There was no sulphuretted hydrogen, and only a little ammonia; the $CO_2$ was from 1·49 to 2·26 volumes per 1000, and varied inversely as the height of the ground-water, which was very near the surface. This relation, however, was not constant at a depth of 6 to 10 feet. Fodor experimented on air at four stations from depths of 4, 2, and 1 metre. At the lowest depth the mean $CO_2$ was 107·5 per 1000; at the depth of 1 metre it was as little as 3·7 in one station. The great amount of $CO_2$ points to very intense chemical changes in the ground, especially in the deep strata, but at the same time it may be very variable in different places. The amount of oxygen was in a measure inversely as the $CO_2$. At a depth of 4 metres (13 feet) the air would be irrespirable, and would extinguish a light, as it contained 13·85 per cent. of $CO_2$ and only 7·46 of oxygen. (How many cellars go as deep as 13 feet into the ground, and this cellar air feeds the house with air !) From the examination of the organic matter he comes to the conclusion that it is not its oxidation on the spot that produces the $CO_2$, and that therefore the latter cannot be taken as a measure of impurity, depending as it does to a large extent upon the *permeability* of the soil.* He found no sulphuretted hydrogen, but a good deal of nitric acid and ammonia, the relative quantities depending upon free access of air or otherwise. As regards moisture, the mean percentage of humidity was 80·7 at 2 metres and 93·8 at 4. Lewis and Cunningham, in their observations at Calcutta, found results somewhat similar to those of Fodor, the $CO_2$ being greatest at the lower strata examined.

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* 6th Report of the Board of Health, Massachusetts, 1875.

† Deutsche Vierteljahrschrift für öffentliche Gesundheit. bd. vii. p. 205, 1875.

‡ The Soil in its relation to Disease, Calcutta, 1875.

*The amount of air in soils* can be roughly estimated, in the case of rather loose rocks, by seeing how much water a given bulk will absorb, which can be done by measuring the water, before and after the weighed or measured rock is inserted in it, or by weighing the rock after immersion. But a more exact plan is to weigh a piece of the rock when dry; to thoroughly saturate it with water, and weigh again, so as to obtain the weight of the water it has taken up. The specific gravity of the rock having been previously determined in the ordinary way, the calculation is—

$$\frac{\text{Weight of water taken up} \times 100,}{\text{Weight of dry rock} \div \text{specific gravity,}} = \text{percentage of air.}$$

When the soil is loose, Pettenkofer adopts the following plan :—Dry the loose soil at 212° Fahr., and powder it, but without crushing it very much ; put it into a burette, and tap it so as to expel the air from the interstices as far as possible; connect another burette by means of an elastic tube with the bottom of the first burette and clamp it on; pour water into No. 2 burette, and then, by pressing the clamp, allow the water to rise through the soil until a thin layer of water is seen above it; then read off the amount of water thus gone out of the second burette. The calculation—

$$\frac{\text{Amount of water used} \times 100}{\text{Cubic centimetres of dry soil}} = \text{percentage of air.}$$

The subterranean atmosphere thus existing in many loose soils and rocks is in continual movement, especially when the soils are dry ; the chief causes of movement are the diurnal changes of heat in the soil, and the fall of rain, which must rapidly displace the air from the superficial layers, and at a later date, by raising the level of the ground water, will slowly throw out large quantities of air from the soil. Fodor considers the temperature of the air, the ground temperature, the action of the winds, rainfall, barometric pressure, and level of ground water to be all influential in causing movement of the ground air and consequent relative change in its constituents. As far as the $CO_2$ was concerned, Lewis and Cunningham found that the air temperature and wind were both inoperative, whilst the moisture had the greatest influence on the upper strata, and the ground-water on the lower

Local conditions must also influence the movement; a house artificially warmed must continually be fed with air from the ground below, and doubtless this air may be drawn from great depths. Coal gas escaping from pipes, and prevented from exuding by frozen earth on the surface, has been known to pass sideways for some distance into houses. The air of cesspools and of porous or broken drains will thus pass into houses, and the examination of drains alone often fails to detect the cause of effluvia in the house.

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* Fodor attempts to distinguish (but hardly successfully) between porosity and permeability.

The unhealthiness of houses built on "made soils," for some time after the soils are laid down, is no doubt to be attributed to the constant ascent of impure air from the impure soil into the warm houses above.

To hinder the ascent of air from below into a house is therefore a sanitary point of importance, and should be accomplished by paving and concreting the basement, or, in some cases, by raising the house on arches off the ground. The improvement of the health of towns, after they are well paved, may partly be owing to lessening of effluvia, though partly also to the greater ease of removing surface impurities. In some malarious districts great benefit has been obtained by covering the ground with grass, and thus hindering the ascent of the miasm.

As a rule, it is considered that loose porous soils are healthy, because they are dry, and, with the qualification that the soil shall not furnish noxious effluvia from animal or vegetable impregnation, the rule appears to be correct. It is, however, undoubted that dry and apparently tolerably pure soils are sometimes malarious, and this arises either from the soils being really impure, or from their porosity allowing the transference of air from considerable distances. Even on the purest soils it is desirable to observe the rule of cutting off the subsoil air from ascent into houses.

The diseases which have been attributed to telluric effluvia are—

Paroxysmal fevers.
Enteric (typhoid) fever.
Yellow fever.
Bilious remittent fever.
Cholera.
Dysentery.

The questions connected with these effluvia will be noticed farther on.

## THE WATER IN THE SOIL.

The water present in soils is divided into moisture and ground water. When air as well as water is present in the interstices, the soil is merely moist. The ground water must be defined, with Pettenkofer, as that condition in which all the interstices are filled with water, so that, except in so far as its particles are separated by solid portions of soil, there is a continuous sheet of water. Other definitions of ground water have been given, but it is in this sense it is spoken of here.

*Moisture of Soil.*—The amount of moisture depends on the power of the soil to absorb and retain water, and on the supply of water to the soil either from rain or ground water. With respect to the first point, almost all soils will take up water. Pfaff* has shown that dried quartz sand on a filter can take up as much as 20 per cent. of water, and though in the natural condition in the soil the absorption would not be so great, there is no doubt that even the hardest sands retain much moisture. After several months of long continued drought, Mr Church found a light calcareous clay loam subsoil to contain from 19 to 28 per cent. of water.

A loose sand may hold 2 gallons of water in a cubic foot, and ordinary sandstone may hold 1 gallon. Chalk takes 13 to 17 per cent.; clay, if not very dense, 20; humus, as much as 40 to 60, and retains its strongly. The so-called "cotton soil" of Central India, which is derived from trap rock, absorbs and retains water with great tenacity; the driest granite and marbles will contain from ·4 to 4 per cent. of water, or about a pint in each cubic yard.

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* Zeitsch für Biologie, band iv. p. 249.

The moisture in the soil is derived partly from rain to which no soil is absolutely impermeable, as even granite, clay slate, and hard limestone may absorb a little. Practically, however, soils may be divided into the impermeable (unweathered granite, trap and metamorphic rocks, clay slate, dense clays, hard oolite, hard limestone and dolomite, &c.) and permeable (chalk, sand, sandstones, vegetable soils, &c.) The amount of rain passing into a soil is influenced, however, by other circumstances—by the declivity and inclination of the soil; by the amount of evaporation, which is increased in summer; by hot winds; and by the rapidity of the fall of rain which may be greater than the soil can absorb. On an average, in this country, about 25 per cent. of the rain penetrates into the sand rocks, 42 per cent. into the chalk, and from 60 to 96 per cent. into the loose sands. The rest evaporates or runs off the surface by the lines of natural drainage. The rapidity with which the rain water sinks through soil evidently varies with circumstances; in the rather dense chalks it has been supposed to move three feet downwards every year, but in the sand its movement must be much quicker.

The moisture of the soil is not, however, derived solely from the rain; the ground water by its own movement of rising and falling, and evaporation from the surface of the subterranean water-sheet, and capillary attraction, makes the upper layers of the soil wet. By these several agencies the ground near the surface is in most parts of the world kept more or less damp.

*Determination of Moisture in the Soil.*—By drying 10 grammes at a temperature of 220° Fahr., then weighing, exposing to air, and observing the increase of weight, an idea is formed of the amount of moisture, and of the hygrometric properties of the soil. If the dried soil is put over water under a bell jar, it will be exposed to air saturated with moisture, or by observing the dry and wet bulb thermometers, the humidity of the air at the time can be noted.

*The Ground or Subsoil Water.*—The subterranean sheet of water is at very different depths below the surface in different soils; sometimes it is only 2 or 3 feet from the surface, in other cases as many hundreds. This depends on the compactness or permeability of the soil, the ease or difficulty of outflow, and the existence or not of an impermeable stratum near or far from the surface. The underground sheet of water is not necessarily horizontal, and in some places it may be brought nearer to the surface than others by peculiarities of ground. The water is in constant movement, in most cases flowing towards the nearest water courses[*] or the sea; the rate of movement has not yet been perfectly determined. In Munich, Pettenkofer reckons its rate as 15 feet daily; the high water in the Elbe moves the ground water in the vicinity at the rate of about 7 or 8 feet daily.

The rate of movement is not influenced solely by compactness or porosity of soil, or inclination. The roots of trees exert a great influence in lessening the flow; and, on the other hand, water runs off more rapidly than before in a district cleared of trees. The level of the ground water is constantly changing. It rises or falls more or less rapidly and at different rates in different places; in some cases its movement is only a few inches either way, but in most cases the limits between its highest and lowest levels in the year are several feet (in Munich about 10). In India the changes are greater. At Saugor, in Central India, the extremes of the soil water are from a few inches from surface (in the rains) to 17 feet in May. At Jubbulpore it is from 2 feet from surface to 12 or 15.

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[*] In confirmation of this it has been shown by Virchow (Reinigung und Entwässerung Berlins, 1873) that the well water near the Spree is higher (in one case 5 feet) than the river; the ground water is not derived from the river, but flows towards it (p. 31), and is influenced by it only as it finds a ready or obstructed entrance on account of the varying amount of water in the Spree. The height of the Spree, therefore, cannot give a correct measure of the height of water in the neighbouring wells, though the ground water is influenced by the river allowing it to run off or holding it back. The movement of the ground water appears to be extremely slight in Berlin; in fact in some parts it is almost stagnant. There are two soils at Berlin, alluvial and diluvial, which furnish ground water of different composition; Virchow, therefore, terms the water of the diluvial or lower stratum the "underground water" (Untergrundwasser), but this term does not appear a very good one.

The *causes of change* in the level of the ground water are the rainfall, pressure of water from rivers or the sea, and alterations in outfall, either increased obstruction or the reverse. The effect of the rainfall is sometimes only traceable weeks or even months after the fall, and occasionally, as in plains at the foot of hills, the level of the ground water may be raised by rainfalls occurring at great distances. The pressure of the water in the Rhine has been shown to affect the water in a well 1670 feet away.[*]

*Diseases connected with Moisture and Ground Water.*—Dampness of soil may presumably affect health in two ways—1*st*, By the effect of the water, *per se*, causing a cold soil, a misty air, and a tendency in persons living on such a soil to catarrhs and rheumatism; and, 2*d*, By aiding the evolution of organic emanations. The decomposition which goes on in a soil is owing to four factors, viz., presence of decomposable organic matters (animal or vegetable), heat, air, and moisture. These emanations are at present known only by their effects; they may be mere chemical agencies, but more probably they are low forms of life which grow and propagate in these conditions. At any rate, moisture appears to be an essential element in their production. The ground water is presumed to affect health by rendering the soil above it moist, either by evaporation or capillary attraction, or by alternate wettings and dryings.

A moist soil is cold, and is generally believed to predispose to rheumatism, catarrh, and neuralgia. It is a matter of general experience that most persons feel healthier on a dry soil.

In some way which is not clear, a moist soil produces an unfavourable effect on the lungs: at least in a number of English towns, which have been sewered, and in which the ground has been rendered much drier, Buchanan has shown that there has been a diminution in the number of deaths from "phthisis."[†] Dr Bowditch of Boston (U.S.), and Dr Middleton of Salisbury, noticed the same fact some years ago. Buchanan's evidence is very strong as to the fact of the connection, but the nature of the link between the two conditions of drying of soil and lessening of certain pulmonary diseases is unknown. It is curious how counter the observation runs to the old and erroneous view, that in malarious (and therefore wet) places there is less phthisis.

A moist soil influences greatly the development of the agent, whatever it may be, which causes the paroxysmal fevers. The factors which must be present to produce this agent are heat of soil (which must reach a certain point = isotherm of 65° Fahr. of summer air temperature), air, moisture, and some impurity of soil, which in all probability is of vegetable nature. The rise and fall of the ground water by supplying the requisite degree of moisture, or, on the contrary, by making soil too moist or too dry, evidently plays a large part in producing or controlling periodical outbreaks of paroxysmal fevers in the so-called malarious countries. The development of malaria may be connected either with rise or with fall of the ground water. An impeded outflow which raises the level of the ground water has, in malarious soils, been productive of immense spread of paroxysmal fevers. In the making of the Ganges and Jumna Canals, the outflow of a large tract of country was impeded, and the course and extent of the obstruction was traced by Dempster and Taylor by the almost universal prevalence of paroxysmal fevers and enlarged spleens in the inhabitants along the banks.* The severe and fatal fever which has prevailed in Burdwan, in Lower Bengal, for the last ten years, appears to be in part owing to the obstruction to the natural drainage from mills and from blockage of water courses.† In some cases relative obstruction comes into play; *i.e.*, an outfall sufficient for comparatively dry weather is quite inadequate for the rainy season, and the ground water rises. At Pola, in Istria, for example, there are no marshes, but in the summer sometimes half, sometimes 90 per cent. of all cases are malarious; the reason is, that a dense clay lies a little below an alluvial soil, and the only exit for the rain is through two valley-troughs, which cannot carry off the water fast enough in the wet season,‡ from February to May.

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[*] In a place near the Hamble River (Hampshire) I found the tide affecting the water of a well at a distance of 2240 feet; the well itself being 83 feet deep and 140 feet above mean-water level. (F. de C.) "Lectures on State Medicine," Smith and Elder. p. 91, 1875.

[†] Buchanan, Ninth and Tenth Reports of the Medical Officer to the Privy Council, 1866, p. 48, and 1867, p. 57. As the term "phthisis" is a general one, and includes all the fatal diseases of the lungs, with destruction of lung-tissue (tuberculous and inflammatory), as well as other cases of wasting, with pulmonary symptoms, it would be well to translate the word "phthisis" by the phrase "wasting diseases of the lungs."

A remarkable instance of excessive rainfall, causing an outbreak of malarial disease, occurred at Kurrachee, in Scinde, in 1869. The average annual rainfall in Scinde in 11 years (1856–66) was only 6·75 inches; and the greatest rainfall in that time was 13·9 inches (1863). In 1867 the rainfall was 2·73; in 1868 it was 3·36 inches; while in 1869 it reached the unprecedented amount of 28·45 inches, of which 13·18 fell in July, and 8·39 inches in September. April, May, October, November, and December were rainless. The 1st Batt. 21st Regiment had the following attacks of paroxysmal fever per 1000 of strength :—In April, none; in May, 9; in June, 39; in July, 30; in August, 93; September, 105; in October, 198; in November, 1004; and in December, 644. In December the regiment was embarked for Madras, as it had "thoroughly lost heart." The disease was not fatal, as the death rate for the year, from all causes, was only 25·7 per 1000. At Kurrachee, as the rainfall is usually so small, the ground dries fast, and is then non-malarious. The ground is flat, and there is no subsoil drainage. In 1866, when there was heavy rainfall (13·75 inches), there was also a development of malarial disease, which was continued in 1867.

The opposite result, viz., an increased outflow lowering the subsoil water, has been observed in drainage operations, and very malarious places have been rendered quite healthy by this measure, as in Lincolnshire, and many parts of England. The case of Boufaric, in Algeria, is a good instance; successive races of soldiers and colonists had died off, and the station had the worst reputation. Deep drainage was resorted to, the level of the ground water was lowered less than 2 feet. This measure, and a better supply of drinking-water, have reduced the mortality to one-third.

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* The observations of Dempster and Taylor on the Jumna Canal have been lately confirmed by Ferguson (Sanitary Administration of the Punjab for 1871, Appendix IV.), who has investigated the effect on malarious disease on the Bári Doáb Canal district; he found canal irrigation increased malarious fever, and apparently by raising the soil-water levels.

† Dr Derby (3d Report of the State Board of Health of Massachusetts, Boston, 1872) points out how ague has been produced by obstructions to out-flow, such as tide-mills, &c. So long ago as 1828, authority to remove a dam was obtained on account of injury to health. See also case recorded by Dr Cattell in Natal, Army Medical Reports, vol. xiii. 1871, p. 178, produced by natural causes.

‡ Dr Jilck, in Archiv. der Heilk, 1870, p. 493.

A case mentioned by Pettenkofer* is also very striking as to the effect of subsoil drainage on some kind of fever in horses. Two royal stables near Munich, with the same arrangements as to stalls, food, and attendance, and the same class of horses, suffered very unequally from fever; horses sent from the unhealthy to the healthy stables did not communicate the disease. The difference between the two places was, that in the healthy stables the ground water was 5 to 6 feet, in the unhealthy only 2½ feet from the surface. Draining the latter stables, and reducing the ground water to the same height, made these stables as healthy as the others.

Typhoid (enteric) fever has also been supposed to be connected with changes in moisture of the soil, owing to rising and falling of the ground water. Professor Pettenkofer's observations on the wells of Munich led Buhl to the discovery that in that city there is a very close relation between the height of the ground water and the fatal cases of typhoid;† the outbreaks of typhoid fever occurred when the ground water was lowest, and especially when, after having risen to an unusual height, it had rapidly fallen. Pettenkofer has repeated and extended the inquiry with the same results. The point has been also numerically investigated by Seidel ‡ in Munich and Leipzig for the years 1856–64 and 1865–73, and from a mathematical consideration of the numbers he concludes that, according to the theory of probabilities, it is 36,000 to 1 that there is, in each period, a connection between the two occurrences.§ Other observations in Germany are confirmatory,|| but in this country the connection has not been traced. In some outbreaks of enteric fever, the ground water has been rising and not falling; and in other instances the attacks have been traced to impure drinking-water or milk, to sewer emanations, or to personal contagion, and the agency of the ground water has appeared to be quite negative. Dr Buchanan¶ has quoted a case, in which the sinking of the ground water and the outbreak of fever were coincident, and yet the connection was, so to speak, accidental, for the efficient cause of the outbreak was the poisoning of the drinking water with typhoid evacuations. And he also points out that when the ground water has actually been lowered in certain English towns by drainage operations, typhoid fever has not increased as it should do, according to theory, but has diminished, owing to the introduction of pure water from a distance. He thus thinks that, while a connection between the prevalence of typhoid fever and sinking of the ground water must be admitted to exist, it is indirect, and the true cause of the fever is

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* Quoted by Kirchner, Lehrb. der Mil-Hygiene, 1869, pp. 217, 218.

† Zeitschrift für Biologie, band i. p. 1.

‡ Zeitsch. für Biologie, band i. p. 221, and band ii. p. 145.

§ Ranke, however, points out that no typhoid exists in the neighbourhood of Munich, but what is imported from Munich, although soil and ground water are the same. Munich has a soil consisting of fine sand, with a peculiar power of holding nitrogenous substances; it is provided with cess-pools, from which more than 90 per cent. of the contents soak into the surrounding soil, and, as the streets are well paved, the houses are the only outlets for the foul soil-air.

Virchow, in his Report on the Sewerage of Berlin, shows that the mortality is greatest in July and August, the curve corresponding accurately with the variation of the ground water, the death-rate being greatest at the lowest level; this is chiefly due to deaths under one year. At the lowest level there is every year a little epidemic of typhoid. At Zürich in 1872 the results were directly opposed to Pettenkofer's views (See Lectures on State Medicine, p. 101) Geissler considers the influence of the rise and fall of the ground water a local matter, and agrees with Rudolph Rath in attributing the typhoid of Berlin to contaminated water. The case of water transmission (which he quotes from Hägler) in the village of Lausen is a very conclusive one. (Schmidt's Jahrbüch. 1874, No. 2, 185; also Archiv für Klin. Medicin, 1873, p. 237; see also an abstract in the Report on Hygiene, Army Med. Reports. vol. xv. p. 197).

Vogt of Bern (Trinkwasser oder Bodengase) strongly supports Pettenkofer's views, and considers the propagation by drinking-water as illusory.

|| Buxbaum, Der Typhus in der Kaserne zu Neustift; Zeitsch. für Biologie, band vi. p. 1. This seems strong evidence in favour of Pettenkofer's view.

¶ Medical Times and Gazette, March 1870.

impurity of the drinking-water. Pettenkofer has replied to this view,[*] and denies, from actual analysis, the fact of the contamination of the drinking-water in typhoid outbreaks.

At the present moment the observations of Pettenkofer, and the case of the barracks at Neustift, recorded by Buxbaum, are certainly in favour of the opinion that a direct connection may exist in some cases between the sinking of the ground water and outbreaks of typhoid; but the frequency and extent of the connection remains to be determined, and in this country, at any rate, the other conditions of spread of typhoid appear to be far more common.

Assuming the truth of the connection, the other conditions which Pettenkofer considers necessary, besides a rapid sinking of ground water after an unusual rise, are impurity of the soil from animal impregnation, heat of soil, and the entrance of a specific germ.[†]

A very similar view is held by Pettenkofer in respect of cholera, and he has advanced many striking arguments[‡] to show that while sporadic cases of cholera may occur, that there will be no wide-spread epidemic, unless certain conditions of soil are present, viz., an impure porous soil, which has recently been rendered moist by a rise of ground water, and then has been penetrated by air during the fall of ground water, and into which the specific germ (Keim) of cholera has found its way. As in the case of typhoid fever, Pettenkofer formerly denied that cholera could be produced by impure drinking-water, but at the Sanitary Conference at Vienna in 1874 he admitted the occasional propagation in this way.[§]

In Germany Pettenkofer's views on the spread of cholera have not met with universal acceptance,[||] though there are several instances in support. In India the weight of the evidence is at present against Pettenkofer's views;[¶] but as investigations are now going on which will in a few years settle the point, it is desirable at present to refrain from forming a decided opinion, except in so far that we may feel sure that the singularly localised outbreaks which sometimes occur in India are quite unconnected with any subsoil-water variations.

In the report of MM. Lewis and Cunningham (*op. cit.*) it is shown that the cholera at Calcutta in 1873–4 followed the curve of the ground-water level inversely, exactly in accordance with Pettenkofer's views.

Dysentery and the so-called bilious remittent fevers, which occur in foul camps and on ground largely contaminated by animal impurities, may be conjectured to be also influenced by variations in the ground water, but satisfactory evidence has not yet been given. In the Calcutta Report, above cited, the maximum of fever corresponded with the maximum of $CO_2$ in the soil atmosphere, and with the highest ground-water level. Dysentery, on the other hand, showed two maxima, one at the rise of the water-level, and the other at the corresponding point of the fall.

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[*] Ibid., June 1870; and Vierteljahrschrift für offentliche. Gesundsheitspflege, 1870, band ii. pp. 176, 197.

[†] Vierteljahrschrift für offentl. Ges., band ii. p. 181.

[‡] Among his many essays, I would especially refer to his Analysis of the Reasons of the Immunity of Lyons from Cholera. (Zeitsch. für Biol., band iv. p. 400).

[§] It is, of course, to be understood that the impurity which aids in producing cholera is derived from persons ill with the disease. For a discussion on Pettenkofer's views on this point, I beg to refer to my Report on Hygiene for 1872, in the Army Med. Department Report, vol. xiii. (1873).

[||] A careful analysis of this subject is contained in F. Küchenmeister's work (Verbreitung der Cholera, 1872), and the work by F. Sander (Unters. über die Cholera, 1872). Dr Frank (health officer of Munich), believes that the cholera in 1873–4, was imported from Vienna, and points out that in 1873 the ground water and death-rate were not in accordance with Pettenkofer's theory. (See Report on Hygiene, Army Med. Report, vol. xv. p. 208).

[¶] Townsend's Report's on the Cholera in Central India contain so many cases where ground water could have had no influence, that it appears impossible to accept Pettenkofer's theory. In Dr Cornish's Report for 1871 are some good observations on subsoil water, which if carried out in the same way for a few years will decide this question.

*Measurement of the Ground Water.*—The height at which water stands in wells is considered to give the best indication of the height of the ground water. Professor Pettenkofer uses a rod on which are fixed a number of little cups, and when let down into the well and drawn up again, the uppermost cup, which contains water, marks, of course, the height of the water; the length of the cord or rod used for letting down the cups being known, the changing level of the well can be estimated to within half an inch. Some precautions are necessary in making these observations; if a rope is used, it may stretch with use or in wet weather, or contract in a dry hot wind, and thereby make the observation incorrect; local conditions of wells, proximity to rivers, &c., must be learnt, else what may be termed local alterations in a well may be wrongly supposed to mean changes in the general level of the ground water. It is necessary, therefore, to make the observations simultaneously in many wells and over a considerable district. The observations should be made not less often than once a fortnight, and oftener if possible, and be carried on for a considerable time before any conclusions are drawn.*

*Method of rendering Soil Drier.*—There are two plans of doing this,—deep drainage and opening the outflow. The laying down of sewers often carries off water by leaving spaces along the course of the sewers; in some cases special drains for ground water have been laid by the side of the sewers, and in very wet soils this seems a good measure. Deep soil drainage (the drains being from 8 to 12 feet deep and 10 to 20 feet apart) is useful in all soils except the most impermeable, and in the tropics should be carried out even on what are apparently dry sandy plains.

In some cases soil may be rendered drier by opening the outflow. This is an engineering problem which physicians can only suggest. The clearing of water-courses, removal of obstructions, and formation of fresh channels, are measures which may have an effect over very large areas which could not be reached by ordinary drainage.

## SUB-SECTION II.

## SOLID CONSTITUENTS OF THE SOIL.

There are certain general features which can be conveniently considered first.

1. *Conformation and Elevation.*—The relative amounts of hill and plain; the elevation of the hills; their direction; the angle of slope; the kind, size, and depth of valleys; the chief water-sheds, and the direction and discharge of the water-courses; the amount of fall of plains, are the chief points to be considered.

Among hills, the unhealthy spots are inclosed valleys, punch-bowls, any spot where the air must stagnate; ravines, or places at the head or entrance of ravines.

In the tropics, especially, ravines and nullahs are to be avoided, as they are often filled with decaying vegetation, and currents of air frequently traverse them. During the heat of the day the current of air is up the ravine; at night down it. As the hills cool more rapidly than the surrounding plains, the latter current is especially dangerous, as the air is at once impure and cold. The worst ravine is a long narrow valley, contracted at its outlet, so as to dam up the water behind it. A saddleback is usually healthy, if not too much exposed; so are positions near the top of a slope. One of the most difficult points to determine in hilly regions is the probable direction of winds; they are often deflected from their course, or the rapid cooling of the hills at night produces alteration.

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* Pettenkofer also uses a large float which is suspended by a chain travelling over a pulley: this supports an indicator at its other end, which marks the height on a fixed scale.

On plains the most dangerous points are generally at the foot of hills, especially in the tropics, where the water, stored up in the hills, and flowing to the plain, causes an exuberant vegetation at the border of the hills.

A plain at the foot of hills may be healthy, if a deep ravine cuts off completely the drainage of the hill behind it.

The next most dangerous spots are depressions below the level of the plain, and into which therefore there is drainage. Even gravelly soils may be damp from this cause, the water rising rapidly through the loose soil from the pressure of higher levels.

Elevation acts chiefly by its effect in lessening the pressure of the air, and in increasing the rapidity of evaporation (see CLIMATE). It has a powerful effect on marshes; high elevations lessening the amount of malaria, partly from the rapid evaporation, partly from the greater production of cold at night. Yet, malarious marshes may occur at great elevations, even 6000 feet (Erzeroum and Mexico).

2. *Vegetation.*—The effect of vegetation on ground is very important. In cold climates the sun's rays are obstructed, and evaporation from the ground is slow; the ground is therefore cold and moist, and the removal of wood renders the climate milder and drier. The extent to which trees impede the passage of water through the soil is considerable.

In hot countries vegetation shades the ground, and makes it cooler. The evaporation from the surface is lessened; but the evaporation from the vegetation is so great as to produce a perceptible lowering effect on the temperature of a place. Pettenkofer has lately calculated that an oak tree which had 751,592 leaves, had during the summer months (May–October) an evaporation equal to 539·1 centimetres (=212 inches), while the rainfall was only 65 centimetres (=25·6 inches); so that the evaporation was 8⅓ times the rainfall; this shows how much water was abstracted from the soil, and how the air must have been moistened and cooled.*

The hottest and driest places in the tropics are those divested of trees.†

Vegetation produces also a great effect on the movement of air. Its velocity is checked; and sometimes in thick clusters of trees or underwood the air is almost stagnant. If moist and decaying vegetation be a coincident condition of such stagnation, the most fatal forms of malarious disease are produced.

Vegetation may thus do harm by obstructing the movement of air; on the other hand, it may guard from currents of impure air. The protective influence of a belt of trees against malaria is most striking.

In a hygienic point of view, vegetation must be divided into herbage, brushwood, and trees; and these should be severally commented on in reports.

Herbage is always healthy. In the tropics it cools the ground, both by obstructing the sun's rays, and by aiding evaporation; and nothing is more desirable than to cover, if it be possible, the hot sandy plains of the tropics with close-cut grass.

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* Recent observations in Algeria (Gimbert), show that the *Eucalyptus globulus* absorbs and evaporates 12 times the rain-fall; extremely malarious places being rendered healthy in this way in four or five years.

† It has been proposed (by Mr. Milne Home) to plant trees at Malta, with the view of improving and regulating the water-supply.

Mr Robert L. Stevenson has considered the thermal influence of forests, in a paper in the Proceedings of the Royal Society of Edinburgh, (19th May 1873). Single trees act as bad conductors; the air of forests is generally cooler than free air, and certainly cooler than cleared lands; forests heat the air during the day and chill it at night.

Brushwood is frequently bad, and should often be removed. There is, however, evidence that the removal of brushwood from a marsh has increased the evolution of malaria, and that, like trees, brushwood may sometimes offer obstruction to the passage of malaria. It must also be remembered that its removal will sometimes, on account of the disturbance of the ground, increase malarious disease for the time; and therefore, in the case of a temporary camp in a hot malarious country, it is often desirable to avoid disturbing it. When removed, the work should be carried on in the heat of the day, *i.e.*, not in the early morning, or in the evening.

Trees should be removed with judgment. In cold countries they shelter from cold winds; in hot, they cool the ground; in both, they may protect from malarious currents. A decided and pernicious interference with the movement of air should be almost the only reason for removing them. In some of the hottest countries of the world, as in Southern Burmah, the inhabitants place their houses under the trees with the best effects; and it was a rule with the Romans to encamp their men under trees in all hot countries.

The kind of vegetation, except as being indicative of a damp or dry soil, does not appear to be of importance.

*Absorption of Heat.*—The heat of the sun is absorbed in different amounts by different soils equally shielded or unshielded by vegetation. The colour of the soil and its aggregation seem chiefly to determine it. The dark, loose, incoherent sands are the hottest; even in temperate climates Arago found the temperature of sand on the surface to be 122° Fahr., and at the Cape of Good Hope Herschel observed it to be no less than 159°.* The heating power of the sun's rays is indeed excessive. In India, the thermometer placed on the ground and exposed to the sun will mark 160° (Buist), while 2 feet from the ground it will only mark 120°. Buist thinks that if protected from currents of air it would mark 212° when placed on the ground. The absorbing and radiating powers of soil are not necessarily equal, though they may be so. Generally the radiating power is more rapid than the absorbing; soils cool more rapidly than they heat. Some of the marshes in Mexico cool so rapidly at night that the evolution of malaria is stopped, and the marsh is not dangerous during the night. A thermometer marked 32° Fahr. on the ground, while 16 feet above the ground it marked 50° Fahr. (Jourdanet).

In Calcutta, Lewis and Cunningham (*op. cit.*) found that the temperature of the soil varied with the season. In hot weather the thermometer stood highest in the air, next highest in the upper stratum of the soil, and lowest in the lower stratum. In cold weather the conditions were exactly reversed, the air being coolest and the lowest stratum of soil the hottest. During rain, however, these relations were not constant.

With regard to absorbing power, the following table by Schübler contains the only good experiments at present known :—

*Power of retaining heat ; 100 being assumed as the standard.*

| | | | |
|---|---|---|---|
| Sand with some lime, | 100 | Clayey earth, | 68·4 |
| Pure sand, | 95·6 | Pure clay, | 66·7 |
| Light clay, | 76·9 | Fine chalk, | 61·8 |
| Gypsum, | 73·2 | Humus, | 49 |
| Heavy clay, | 71·11 | | |

The great absorbing power of the sands is thus evident, and the comparative coldness of the clays and humus. Herbage lessens greatly the absorbing power of the soil, and radiation is more rapid. On the Orinoco, a naked granite-rock has been known to have a temperature of 118° Fahr., while an adjacent rock, covered with grass, had a temperature 32° lower.

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* Meteorology, p. 4.

In cold countries, therefore, the clayey soils are cold, and as they are also damp, they favour the production of rheumatism and catarrhs; the sands are, therefore, the healthiest soils in this respect. In hot countries the sands are objectionable from their heat, unless they can be covered with grass. They sometimes radiate heat slowly, and therefore the air is hot over them day and night.

The sun's rays cause two currents of heat in soil: one wave diurnal, the heat passing down in temperate climates to about 4 feet in depth during the day, and receding during the night—the depth, however, varying with the nature of the soil, and with the season; the other wave is annual, and in temperate climates the wave of summer heat reaches from 50 to 100 feet. The line of uniform yearly temperature is from 57 to 99 feet below the surface (Forbes).

Not only does the amount of radiation differ in different soils, but a change is produced in the heat by the kind of soil. The remarkable researches of Tyndall have shown, that the heat radiated from granite passes through aqueous vapour much more readily than the heat radiated by water (though the passage is much more obstructed than in dry air). In other words, the luminous heat rays of the sun pass freely through aqueous vapours, and fall on water and granite; but the absorption produces a change in the heat, so that it issues again from water and granite changed in quality; it will be most important for physicians if other soils are found to produce analogous changes.

With regard to the effect of temperature of the soil on disease, it can hardly be doubted that it powerfully influences malaria, and probably also aids the progress of cholera.

*Reflection of Light.*—This is a matter of colour; the white glaring soils reflect light, and such soils are generally also hot, as the rays of heat are also reflected. The effect of glare on the eyes is obvious, and in the tropics this becomes a very important point. If a spot bare of vegetation, and with a white surface, must be used for habitations, some good result might be obtained by colouring the houses pale blue or green.

### *Chemical Composition of the Solid Parts of Soils.*

*Vegetable Matters.*—Almost all soils contain vegetable matter. It exists in three chief forms—deposits, vegetable *débris*, and encrustations. Deposits occur in tracts of land which have been covered by silt brought down by floods, or which have been submerged by subsidence; forests have been thus buried, and again elevated. In the marshes of the Tuscan Maremma, and in many other cases, the vegetable forms can be traced without difficulty to a considerable depth, and the structure is even sometimes little changed, although so vast a period of time has elapsed. Vegetable *débris* produced by the decay of plants lies on, or is washed into, the soil, and in this way the ground may be penetrated to great depths. In some cases, especially in sandy plains at the foot of hills, the rain brings down very finely-divided *débris*, and is filtered as it passes through the soil, so that each particle of sand becomes coated over or encrusted with a film of vegetable matter. If such a plain be subjected to alternate wettings and dryings, and to heat, the conditions of development of malaria may be present in great intensity; although there is not only no marsh, but the sand is to all appearance dry and pure.

*Animal matters.*—The remains of animals are found in all but the oldest rocks; generally the animal constituents have disappeared, but it is remarkable how in some cases, even in geological formations as old as the tertiary strata, some animal matter may be found. On the surface there is perhaps no soil which does not contain some animal matters derived from dead animals or excreta, although, except in special cases, the amount is small. The soil of countries which have been long settled is, however, often highly impure in the neighbourhood of habitations from the refuse (animal and vegetable) which is thrown out. In some loose soils cess-pits used for fifty years have never been emptied, and are still not full, owing to soakage.* Pettenkofer conjectures that in Munich 90 per cent. of the excretions pass into the ground. In clayey soil there is, of course, much less infiltration than in sandy, and often scarcely any. In India, the nitrification of vast tracts of land is for the most part owing to the oxidation of animal refuse.

A means of purification from animal impregnation has been, however, provided by oxidation, and by the influence of growing vegetation. In all soils, except the hottest and driest, animal refuse passes into nitrates, nitrites, and ammonia and fatty hydrocarbons, rather rapidly, and these are eagerly absorbed by vegetation. A means is therefore pointed out which may keep the soil clear from dangerous animal impregnations, and this is no doubt one reason why improvement in public health follows improved cultivation. It has become quite clear that in the plans for the disposal of the human and animal excreta of towns, whether by wet or dry methods, an essential part of the plan is to submit these excreta to the influence of growing plants as soon as possible.

*Mineral matters.*—An immense number of mineral substances are scattered through the crust of the earth, but some few are in great preponderance, viz., compounds of silicon, aluminium, calcium, iron, carbon, chlorine, phosphorus, potassium, and sodium.

In examining the constituents of the soil round any dwellings, the immediate local conditions are of more importance than the extended geological generalisations; it is, so to speak, the house and not the regional geology which is of use. Still the general geological conditions, as influencing conformation and the movement of water and air through and over the country, are of great importance.

1. *The Granitic, Metamorphic, and Trap Rocks.*—Sites on these formations are usually healthy; the slope is great, water runs off readily; the air is comparatively dry; vegetation is not excessive; marshes and malaria are comparatively infrequent, and few impurities pass into the drinking water.

When these rocks have been weathered and disintegrated, they are supposed to be unhealthy. Such soil is absorbent of water; and the disintegrated granite of Hong-Kong is said to be rapidly permeated by a fungus;† but evidence as to the effect of disintegrated granite or trap is really wanting.

In Brazil‡ the syenite becomes coated with a dark substance, and looks like plumbago, and the Indians believe this gives rise to "calentura," or fevers. The dark granitoid or metamorphic trap, or hornblendic rocks in Mysore, are also said to cause periodic fevers; and iron hornblende especially was affirmed by Dr Heyne of Madras to be dangerous in this respect. But the observations of Richter§ on similar rocks in Saxony, and the fact that stations on the lower spurs of the Himalayas on such rocks are quite healthy, negative Heyne's opinion.

2. *The Clay Slate.*—These rocks precisely resemble the granite and granitoid formations in their effect on health. They have usually much

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* Göttisheim in Basle (Das unterirdische Basel, 1868).
† Ost Asiens von C. Friedel, 1863.
‡ M'Williams on Yellow Fever in Brazil, p. 7.
§ Schmidt's Jahrbüch. 1864, No. 5. p. 240.

slope; are very impermeable; vegetation is scanty; and nothing is added to air or to drinking water.

They are consequently healthy. Water, however, is often scarce; and, as in the granite districts, there are swollen brooks during rain, and dry water-courses at other times swelling rapidly after rains.

3. *The Limestone and Magnesian Limestone Rocks.*—These so far resemble the former, that there is a good deal of slope, and rapid passing off of water. Marshes, however, are more common, and may exist at great heights. In that case the marsh is probably fed with water from some of the large cavities, which, in the course of ages, become hollowed out in the limestone rocks by the carbonic acid of the rain, and form reservoirs of water.

The drinking water is hard, sparkling, and clear. Of the various kinds of limestone, the hard oolite is the best, and magnesian is the worst; and it is desirable not to put stations on magnesian limestone if it can be avoided.

4. *The Chalk.*—The chalk, when unmixed with clay and permeable, forms a very healthy soil. The air is pure, and the water, though charged with carbonate of lime, is clear, sparkling, and pleasant. Goitre is not nearly so common, nor apparently calculus, as in the limestone districts.

If the chalk be marly, it becomes impermeable, and is then often damp and cold. The lower parts of the chalk, which are underlaid by gault clay, and which also receive the drainage of the parts above, are often very malarious; and in America, some of the most marshy districts are on the chalk.

5. *The Sandstones.*—The permeable sandstones are very healthy; both soil and air are dry; the drinking water is, however, sometimes impure. If the sand be mixed with much clay, or if clay underlies a shallow sand-rock, the site is sometimes damp.

The hard millstone grit formations are very healthy, and their conditions resemble those of granite.

6. *Gravels* of any depth are always healthy, except when they are much below the general surface, and water rises through them. Gravel hillocks are the healthiest of all sites, and the water, which often flows out in springs near the base, being held up by underlying clay, is very pure.

7. *Sands.*—There are both healthy and unhealthy sands. The healthy are the pure sands, which contain no organic matter, and are of considerable depth. The air is pure, and so is often the drinking water. Sometimes the drinking water contains enough iron to become hard, and even chalybeate. The unhealthy sands are those which, like the subsoil of the Landes, in south-west France, are composed of siliceous particles (and some iron), held together by a vegetable sediment.

In other cases sand is unhealthy, from underlying clay or laterite near the surface, or from being so placed that water rises through its permeable soil from higher levels. Water may then be found within 3 or 4 feet of the surface; and in this case the sand is unhealthy, and often malarious. Impurities are retained in it, and effluvia traverse it.

In a third class of cases, the sands are unhealthy because they contain soluble mineral matter. Many sands (as, for example, in the Punjab), contain much carbonate of magnesia and lime salts, as well as salts of the alkalies. The drinking water may thus contain large quantities of sodium chloride, sodium carbonate, and even lime and magnesian salts and iron. Without examination of the water, it is impossible to detect these points.

8. *Clay, Dense Marls, and Alluvial Soils generally.*—These are always to be regarded with suspicion. Water neither runs off nor runs through; the air is moist; marshes are common; the composition of the water varies, but it is often impure with lime and soda salts. In alluvial soils there are often

alternations of thin strata of sand, and sandy impermeable clay; much vegetable matter is often mixed with this, and air and water are both impure. Vast tracts of ground in Bengal and in the other parts of India, along the course of the great rivers (the Ganges, Brahmapootra, Indus, Nerbudda, Krishna, &c.), are made up of soils of this description, and some of the most important stations even up country, such as Cawnpore, are placed on such sites.

The deltas of great rivers present these alluvial characters in the highest degree, and should not be chosen for sites. If they must be taken, only the most thorough drainage can make them healthy. It is astonishing, however, what good can be effected by the drainage of even a small area, quite insufficient to affect the general atmosphere of the place; this shows that it is the local dampness and the effluvia which are the most hurtful.

9. *Cultivated Soils.*—Well-cultivated soils are often healthy, nor at present has it been proved that the use of manure is hurtful. Irrigated lands, and especially rice fields, which not only give a great surface for evaporation, but also send up organic matter into the air, are hurtful. In Northern Italy, where there is a very perfect system of irrigation, the rice grounds are ordered to be kept 14 kilometres (= 8·7 miles) from the chief cities; 9 kilometres (= 5·6 miles) from the lesser cities and the forts; and 1 kilometre (= 1094 yards) from the small towns. In the rice countries of India this point should not be overlooked.

10. *Made Soils.*—The inequalities of ground which is to be built upon are filled up with whatever happens to be available. Very often the refuse of a town, the cinders, or dust-heaps, after being raked over, and any saleable part being removed, are used for this purpose. In other cases, chemical or factory refuse of some kind is employed. The soil under a house is thus often extremely impure. It appears, however,* that the organic matters in soil gradually disappear by oxidation and removal by rain, and thus a soil in time purifies itself. The length of time in which this occurs will necessarily depend on the amount of impurity, the freedom of access of air, and the ease with which water passes through the soil. In the soil at Liverpool, made from cinder refuse, vegetable matters disappeared in about three years; textile fabrics were, however, much more permanent; wood and straw, and cloth, were rotten and partially decayed in three years, but had not entirely disappeared. In any made soil, it should be a condition that the transit of water through its exit from the soil shall be unimpeded. The practice of filling up inequalities is certainly, in many cases, very objectionable, and should only be done under strict supervision.

## SUB-SECTION III.

*Malarious Soils.*—Doubts have been expressed whether those paroxysmal fevers, which are curable by quinine, are produced either by telluric effluvia, or by substances passing from the soil into the drinking water. The evidence, however, appears to me conclusive in favour of both these modes of entrance into the body, although the particular agency (whether a plant or some non-organised effluvium) has not been recognised. I presume it may now be assumed that such fevers are not produced by heat or electricity, or great exercise in the sun, or chill, or any other alleged cause of the kind, but must own a special and constant agent which can hardly be a gas. The efficient condition is apparently some kind of decomposition or fermentation going on in the soil, especially when the conditions come together of organic matter in the soil, of moisture, heat, and limited access of air.

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* See Report on the Health of Liverpool, by Dr Burdon Sanderson, and the author, p. 9, *et seq.*

If it be asked, What exact chemical conditions of soil produce the malaria which causes periodical fevers? the answer cannot be given, because no great chemist has ever systematically prosecuted this inquiry, and, in fact, it may be said that, singularly enough, there are few good analyses of malarious soils, although no problem is perhaps more important to the human race. It seems pretty clear that the mineral constituents of the soil are of little or no consequence. Malaria will prevail on chalk, limestone, sand, and even, under special conditions, on granite soils.

The following soils have been known to cause the evolution of the agent causing periodical fevers in the malarious zone.

1. *Marshes.*—Except those with peaty soils, those which are regularly overflowed by the sea (and not occasionally inundated),* and the marshes in the southern hemisphere (Australia, New Zealand, New Caledonia), and some American marshes, which, from some as yet unknown condition, do not produce malaria.

The chemical characters of well-marked marshes are a large percentage of water, but no flooding; a large amount of organic matter (10 to 45 per cent.) with variable mineral constituents; silicates of alumina; sulphates of lime, magnesia and alkalies; carbonate of lime, &c. The surface is flat, with a slight drainage; vegetation is generally abundant.

The analyses of the worst malarious marshes show a large amount of vegetable organic matter. A marsh in Trinidad gave 35 per cent.; the middle layer in the Tuscan Maremma 30 per cent. The organic matter is made up of humic, ulmic, crenic, and apocrenic acids—all substances which require renewed investigation at the hands of chemists. Vegetable matter embedded in the soil decomposes very slowly; in the Tuscan Maremma, which must have existed many centuries, if not thousands of years, many of the plants are still undestroyed. The slow decomposition is much aided by heat, which makes the soil alkaline from ammonia (Angus Smith), and retarded by cold, which makes the ground acid, especially in the case of peaty soils.

It would now seem tolerably certain that the growing vegetation covering marshes has nothing to do with the development of malaria.

2. *Alluvial Soils.*—Many alluvial soils, especially, as lately pointed out by Wenzel,† those most recently formed, give out malaria, although they are not marshy. It is to be presumed that the newest alluvium contains more organic matters and salts than the older formations. Many alluvial soils have a flat surface, a bad outfall, and are in the vicinity of streams which may cause great variations in the level of the ground water. Mud banks also, on the side of large streams, especially if only occasionally covered with water, may be highly malarious; and this is the case also with deltas and old estuaries.

3. The soils of tropical valleys, ravines, and nullahs. In many cases large

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* The effect of salt water on marshes is a problem which has been much debated, and I believe the statement in the text reconciles most opinions. It was the older writers (Sylvius, Lancisi, and Pringle) who insisted on the noxious qualities of exhalations from marshes with water containing salt, and there is certain evidence that the occasional overflowing of the sea in some of the Italian marshes, for example, has been followed by a great development of paroxysmal fevers. But there is much evidence similar to that given by Robert Jackson, who says (Fevers in Jamaica, 1791, p. 4):—"I have never found the neighbourhood of salt marshes, in the different parts of America that I have had an opportunity of visiting, less healthful than the rest of the country; on the contrary, they were frequently more so." And the case of Singapore, which has created such surprise, and is cited even by Hirsch as an exceptional case, is of this kind; the regular tidal overflow, though it causes the development of much sulphuretted hydrogen, prevents the formation of malaria.

† Quoted by Hirsch. Jahresb., für die Ges. Med., 1870, band ii. p. 209.

quantities of vegetable matter collect in valleys, and if there is any narrowing at the outlet of the valley, the overflow of the rains may be impeded. Such valleys are often very malarious, and the air may drift up to the height of several hundred feet.

4. Sandy plains, especially when situated at the foot of tropical hills, and covered with vegetation, as in the case of the "Terai" at the base of some parts of the Himalayan range. In other cases, the sandy plains are at a distance from hills, and are apparently dry, and not much subjected to the influence of variations in the ground water. The analysis of such sand has not been yet properly made, but two conditions seem of importance. Some sands, which to the eye appear quite free from organic admixture, contain much organic matter. Fauré has pointed out that the sandy soil of the Landes in south-west France contains a large amount of organic matter, which is slowly decomposing, and passes into both air and water, causing periodical fevers. This may reasonably be conjectured to be the case with other malarious sands. Then, under some sands, a few feet from the surface, there is clay, and the sand is moist from evaporation. Under a great heat a small quantity of organic matter may thus be kept in a state of change. This is especially the case along the dried beds of water courses and torrents; there is always a subterranean stream, and the soil is impregnated with vegetable matter. In other cases the sands may be only malarious during rains when the upper stratum is moist.

5. Certain hard rocks (granitic and metamorphic) have been already noticed (p. 339), especially when weathered, to have the reputation of being malarious; more evidence is required on this point. As Friedel justly remarks of Hong-Kong, it is not the disintegrated granite, *per se*, which causes the fever, but the soil of the woods and dells, and the clefts in the rocks, which were derived from the granite, and are soon filled with a cryptogamic vegetation.

The magnesian limestone rocks which have been subjected to volcanic action have also been supposed to be especially malarious (Kirk, who instances the rocks at Sukkar), but the evidence has not been yet corroborated.

6. *Iron Soils.*—Sir Ranald Martin has directed attention to the fact that many reputed malarious soils contain a large proportion of iron. No good evidence has been adduced that this is connected with malaria, but the point requires further examination. The red soil from Sierra Leone, which contains more than 30 per cent. of oxides of iron, shows nothing which appears likely to cause malaria.* The peroxide of iron is a strong oxidising agent, readily yielding oxygen to any oxidisable substance, and regaining oxygen from the air. It may, therefore, assist in the oxidation of vegetable matter in an iron soil.†

7. In certain cases attacks of paroxysmal fever have arisen from quite localised conditions unconnected with soil, which seem, however, to give some clue to the nature of the process which may go on in malarious ground.

Friedel‡ mentions that in the Marine Hospital at Swinemünde, near Stettin, a large day-ward was used for convalescents. As soon as any man had been in this ward for two or three days, he got a bad attack of tertian ague. In no other ward did this occur, and the origin of the fever was a mystery, until, on close inspection, a large rain cask full of rotten leaves and brushwood was found; this had overflowed, and formed a stagnant marsh of 4 to 6 square feet close to the doors and windows of the room, which, on account of the hot weather, were kept open at night. The nature of the effluvium was not determined.

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* Analysis of the Red Earth of Sierra Leone, by Assistant-Surgeon J. A. B. Horton, M.D., Army Medical Department Blue-Book, vol. viii. p. 383.

† The surface soil of the Gold Coast (Connor's Hill, Cape Coast Castle), has also been analysed by Mr. J. H. Warden, F.C.S. (Indian Medical Service). It contained only 3·28 per cent. of ferric oxide, and a trace of ferrous oxide; the organic matter was only 4·4 per cent. The surface soil is only eight inches thick, and below this is a stratum of a dark red colour, like burnt bricks, probably containing more iron. The sample above-mentioned was brought home by Surgeon-major J. Fleming, A.M.D. (Army Medical Reports, vol. xiv. p. 264).

‡ Ost. Asiens. Berlin, 1863, p. 338.

Dr Holden* relates an instance in which, on board a ship at sea, eight cases of ague occurred from the emanations of a large quantity of mould which had formed in some closed store-rooms, which were exposed to the bilge water.†

## SECTION II.

## EXAMINATION OF SOIL.

*Mechanical Condition of Soil.*—The degree of density, friability, and penetration by water, should be determined both in the surface and subsoil. Deep holes, 6 to 12 feet, should be dug, and water poured on portions of the soil. Holes should be dug after rain, and the depth to which the rain has penetrated observed. In this way the amount of dryness, the water-level, and the permeability, can be easily ascertained.

The surface or subsoil can also be mechanically analysed by taking a weighed quantity (100 grammes), drying it, and then picking out all the large stones and weighing them, passing through a sieve the fine particles, and finally separating the finest particles from the coarser by mixing with water, allowing the denser particles to subside, and pouring off the finer suspended particles. The weight of the large stones, plus the weight of the stones in the sieve and of the dried coarser particles, deducted from the total weight, gives the amount of the finely divided substance, which is probably silicate of aluminium.

*Temperature.*—The temperature at a depth of 2 or 3 feet, at 2 to 4 o'clock in the afternoon, would be an important point to determine in the tropics, and also the temperature in early morning. At present such observations, though very easily taken, and obviously very instructive, are seldom, if ever made, although a commencement in that direction has been made in the investigations of Messrs Lewis and Cunningham at Calcutta‡. It might also be useful to take a certain depth of soil, say 6 inches, and, placing a thermometer in it, determine the height of the thermometer on exposure to the sun's rays for a given time at a certain hour.

*Chemical Examination.*—The chemical constituents of soil are, of course, as numerous as the elements; more than 500 minerals have been actually named. But certain substances are very rare, and, for the physician, the chief constituents of soils are the following substances or combinations:—Silica, alumina, lime, iron, magnesia, chlorine, carbonic acid, phosphoric acid, nitric acid. A few simple tests are often very useful, if we are uncertain what kind of rock we have to deal with. Few persons could mistake granite, trap, gneiss, or rocks of that class; or clay-slate or crystalline limestone. But fine white sandstones, or freestone, or even fine millstone grit, might be confounded with lime rocks, or magnesian limestone. A few drops of hydrochloric acid will often settle the question, as it causes effervescence in the carbonates of lime and magnesian rocks.*

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* American Journal of Med. Science, January 1866.

† Staff-surgeon P. Mansfield, R.N., recounts an outbreak of yellow remittent fever on board ship at Rio, coincident with the growth of an enormous quantity of gigantic fungus in the hold. It seems unlikely, however, that this was more than a coincidence.

‡ *Op. cit.*

A more complete examination should include the following points:—

1. *Percentage of Water.*—Take 10 grammes of a fair sample of soil, and dry at a heat of 220°; weigh again; the difference is water or volatile substance.

2. *Percentage of volatile matters (including water), destroyed by incineration.*—Take another weighed portion of soil and incinerate at a full red heat; recarbonate with carbonic acid solution, or with ammonium carbonate; heat to expel excess of ammonia; dry and weigh.

3. *Absorption of Water.*—Place the dried soil in a still atmosphere, on a plate in a thin layer, and reweigh in 24 hours; the increase is the absorbed

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* It may be useful to give (from Page's "Handbook of Geological Terms") a few compositions, and to define a few of the common mineralogical words used in geology.

*Quartz.*—Crystallised silica.
*Felspar.*—Silica, alumina (trisilicate of alumina), potash, or soda, and a little lime, magnesia, and ferric oxide, crystallised or amorphous.
*Mica.*—Silica, alumina, ferric oxide and potash, or magnesia, or lime, or lithia.
*Chlorite.*—Mica, but with less silica and more magnesia and iron.
*Granite.*—Composed of quartz, felspar, and mica.
*Syenite.*—Hornblende instead of mica.
*Syenitic granite.*—Quartz, felspar, mica, and hornblende.
*Gneiss.*—Same elements as granite, but the crystals of quartz and felspar are broken and indistinct.
*Hornblende.*—A mineral entering largely into granite and trappean rocks, composed of silica (47 to 60), magnesia (14 to 28), lime (7 to 14), with a little alumina, fluorine, and ferrous oxide.
*Augite.*—Like hornblende, only less silica (does not resist acids).
*Hypersthene.*—Like augite, only with very little lime; it contains silica, magnesia, and iron; resists acids.
*Greenstone.*—Hard granular crystalline varieties of trap, felspar, and hornblende, or felspar and augite.
*Basalt.*—Augite and felspar, olivine, iron pyrites, &c.
*Trap.*—Tabular greenstone and basalt,
*Schist.*—A term applied to the rocks mentioned above, when they are foliated or split up into irregular plates.
*Clay-Slate.*—Argillaceous arenaceous rocks, with more or less marked cleavage.
*Limestone.*—All varieties of hard rocks, consisting chiefly of carbonate of lime.
*Oolite.*—Limestone made up of small rounded grains, compact or crystalline, like the roe of a fish.
*Chalk.*—Soft calcium carbonate.
*Magnesian Limestone.*—Any limestone containing 20 per cent. of a salt of magnesia, frequently not crystallised.
*Dolomite.*—Crystallised magnesian limestone.
*Kunkur.*—A term used in India to denote nodular masses of impure calcium carbonate.
*Gypsum—Selenite.*—Sulphate of calcium.
*Gravel.*—Water-worn and rounded fragments of any rock, chiefly quartz; size, from a pea to a hen's egg.
*Sand.*—Same, only particles less than a pea.
*Sandstone.*—Consolidated sand; the particles held together often by lime, clay, and ferric oxide.
*Freestone.*—Any rock which can be cut readily by the builder; usually applied to sandstone.
*Millstone grit.*—Hard gritty sandstone of the carboniferous series, used for millstones. Grit is the term generally used when the particles are larger and sharper than in ordinary sandstone.
*Clay.*—Silicate of alumina.
*Greensand.*—Lower portion of the chalk system in England; sand coloured by chloritous silicate of iron.
*Marl.*—Lime and clay.
*Laterite.*—A term much used in India to denote a more or less clayey stratum which underlies much of the sand in Bengal, some parts of Burmah, Bombay presidency, &c.
*Conglomerate.*—Rocks composed of consolidated gravels (*i.e.*, the fragments water-worn and rounded).
*Breccia.*—Rocks composed of *angular* (not water-worn) fragments (volcanic breccia, osseous breccia, calcareous breccia).
*Shale.*—A term applied to all clayey or sandy formations with lamination; it is often consolidated and hardened mud.

water. An equal portion of pure sand should be treated in the same way as a standard. It would be well to note the humidity of the air at the time.

4. *Power of holding Water.*—Thoroughly wet 100 grammes, drain off water as far as possible, and weigh; the experiment is, however, not precise.

5. *Substances taken up by Water.*—This is important, as indicating whether drinking water is likely to become contaminated. Rub thoroughly 10 grammes in pure cold water, filter and test for organic matter by chloride of gold, or by evaporation and careful incineration; test also for chlorine, sulphuric acid, lime, alumina, iron, nitric acid (see WATER, page 69, for the several tests).

6. *Substances taken up by Hydrochloric Acid.*—While water takes up the chlorides and the sulphates of the alkalies, nitrates, &c., the greater part of the lime, magnesia, and alumina are left undissolved. The quantity can be best determined by solution in pure hydrochloric acid.

(*a*) To 40 grammes of the soil add one ounce of pure hydrochloric acid, and heat; note effervescence. Add about 100 C.C. of water. Digest for 12 hours. Dry and weigh the undissolved portion.

(*b*) To the acid solution add ammonia. Alumina and oxide of iron are thrown down. Dry and weigh precipitate.

(*c*) To the solution filtered from (*b*) add ammonium oxalate. Dry; wash and burn the calcium oxalate. Weigh as carbonate (see page 81, footnote).

(*d*) To the solution filtered from (*c*) add sodium phosphate. Collect; dry and weigh (100 parts of the precipitate = 79 parts of magnesium carbonate); or determine as pyrophosphate. (See WATER.)

The portion insoluble in hydrochloric acid consists of quartz, clay, silicates of alumina, iron, lime, and magnesia. If it is wished to examine it further, it should be fused with three times its weight of carbonate of sodium, then heated with dilute hydrochloric acid. The residue is silica. The solution may contain iron, lime, magnesia, and alumina. Test as above.

6. *Iron.*—Iron can be determined by the bichromate of potassium, or by the permanganate. As the latter solution is used for other purposes, it is convenient to employ it in this case.

Dissolve 10 grammes of the soil in pure hydrochloric acid free from iron, by aid of heat.

Add a little pure zinc, and heat to convert ferric into ferrous salts. Pour off the solution from the zinc that is still undissolved, and determine iron by potassium permanganate; *i.e.*, heat to 140° and then drop in the solution of permanganate till a permanent but slightly pink colour is given.

### *Preparation of Potassium Permanganate Solution.*

The solution made for the determination of organic matter in water may be used (see page 85), 1 C.C. = 0·7 milligramme of pure iron.

## SECTION III.

## METHOD OF EXAMINING A LOCALITY FOR MILITARY PURPOSES.

A place should be seen at all times of the year, in the wet as well as in the dry seasons, in the autumn and winter as well as in the spring, and at night as well as by day. The following order will be found a convenient one:—

1. *Conformation.*—Height above sea-level and elevation of hills above the plain. (Determine by mercurial barometer or aneroid, or, if possible, get the heights from an engineer.) Angle of declivity of hills; amount of hill and plain; number, course, and characters of valleys and ravines in hills; dip of

strata; geological formation; watersheds and courses; exposure to winds; situation, amount and character of winds; sunlight, amount and duration; rain, amount and frequency; dust.

2. *Composition.*—Mineralogical characters. Presence of animal or vegetable substances; amount and characters.

3. *Covering of soil* by trees, brushwood, grass, &c.

4. *Points for special examination.*—Amount of air; of moisture. Height of subsoil water, at the wettest and driest seasons. Changes in level, and rapidity of change of subsoil or ground water. Condition of vegetable constituents; examination of substances taken up by water, &c.

Such a complete examination demands time and apparatus, but it is quite necessary.

A fair opinion can then be formed; but if a large permanent station is to be erected, it is always desirable to recommend that a temporary station should be put up for a year, and an intelligent officer should be selected to observe the effect on health, to take meteorological observations, and to examine the water at different times of the year. Sometimes a spot more eligible than that originally chosen may be found within a short distance, and the officer should be instructed to keep this point in view.

The medical officer has nothing to do with military considerations or questions of supply, but if he is able to suggest anything for the information of the authorities, he should of course do so.

The opinion of Lind, whose large experience probably surpassed that of his contemporaries, and of our own time, should be remembered.*

In choosing a site for a temporary camp, so elaborate an examination is not possible. But as far as possible the same rules should be attended to. There is, however, one difference—in a permanent station water can be brought from some distance; in a temporary station the water supply must be near at hand, and something must be given up for this.† The banks of rivers, if not marshy, may be chosen, care being taken to assign proper spots for watering, washing, &c., as laid down in the chapter on WATER. A river with marshy banks must never be chosen in any climate, except for the most imperative military reasons; it is better to have the extra labour of carrying water from a distance.

A site under trees is good in hot countries, but brushwood must be avoided.

## SECTION IV.

## PREPARATION OF SITE FOR MILITARY PURPOSES.

In any locality intended to be permanently used, the ground should be drained with pipe drains. Even in the driest of the loose soils this is desirable, especially in hot climates, where the rainfall is heavy. In impermeable rocky districts it is less necessary. The size, depth, and distance of the drains will be for the engineer to determine; but generally deep drains (4 to 8 feet in depth, and 12 to 18 feet apart) are the best. If there is no good fall, it has been proposed to drain into deep pits; but usually an engineer will get a fall without such an expedient. A good outfall, however, should be a point always looked to in choosing a station. These drains are intended to carry off subsoil water, and not surface water. This latter should be provided for by shallow drains along the natural outfalls and valleys. As far as drainage is concerned, we have then to provide for mere surface water, and for the water which passes below the surface into the soil and subsoil.

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* "The most healthy countries in the world contain spots of ground where strangers are subject to sickness. There is hardly to be found any large extent of continent, or even any island, that does not contain some places where Europeans may enjoy an uninterrupted state of health during all seasons of the year." —Lind, *Diseases of Europeans in Hot Climates*, 4th edition, p. 200.

† See Remarks on this point, in the Regulations and Instructions for Encampments, p. 2.

Brushwood, should usually be cleared away, but trees left until time is given for consideration. In clearing away brushwood, the ground in the tropics should be disturbed as little as possible; and if it can be done, all cleared spots should be soon sown with grass. Brushwood should not be removed from a marsh.

In erecting the buildings, the ground should be excavated as little as possible; in the tropics especially hills should never be cut away. The surface should be levelled, holes filled in, and those portions of the surface, on which rain can fall from buildings, well paved, with good side gutters. This is especially necessary in the tropics, where it is of importance to prevent the ground under buildings from becoming damp; but the same principles apply everywhere.

In a temporary camp so much cannot be done; but even here it is desirable to trench and drain as much as possible. It not unfrequently happens in war that a camp intended to stand for two or three days is kept up for two or three weeks, or even months. As soon as it is clear that the occupation is to be at all prolonged, the same plans should be adopted as in permanent stations. The great point is to carry off water rapidly, and it is astonishing what a few well-planned surface drains will do.

The Rules for improving the healthiness of a site may be thus summarised:—

1. Drain subsoil and lower the level of the ground water.
2. Pave under houses, so as to prevent the air from rising from the ground.
3. Pave or cover with short grass all ground near buildings in malarious districts.
4. Keep the soil from the penetration of impurities of all kinds by proper arrangements for carrying away rain, surface, and house water and house impurities.

# CHAPTER IX.

# HABITATIONS.

**Whoever** considers carefully the record of the mediæval epidemics, and seeks to interpret them by our present knowledge of the causes of disease, will, I believe, become convinced that one great reason why those epidemics were so frequent and so fatal was the compression of the population in faulty habitations. Ill-contrived and closely packed houses, with narrow streets, often made winding for the purpose of defence; a very poor supply of water, and therefore a universal uncleanliness; a want of all appliances for the removal of excreta; a population of rude, careless, and gross habits, living often on innutritious food, and frequently exposed to famine from their imperfect system of tillage,—such were the conditions which almost throughout the whole of Europe enabled diseases to attain a range, and to display a virulence, of which we have now scarcely a conception. The more these matters are examined, the more, I believe, shall we be convinced that we must look, not to grand cosmical conditions; not to earthquakes, comets, or mysterious waves of an unseen and poisonous air; not to recondite epidemic constitutions, but to simple, familiar, and household conditions, to explain the spread and fatality of the mediæval plagues.

The diseases arising from faulty habitations are in great measure, perhaps entirely, the diseases of impure air. The site may be in fault; and from a moist and malarious soil excess of water and organic emanations may pass into the house. Or ventilation may be imperfect, and the exhalations of a crowded population may accumulate and putrefy; or the excretions may be allowed to remain in or near the house; or a general uncleanliness, from want of water, may cause a persistent contamination of the air. And, on the contrary, these five conditions insure healthy habitations:—

1. A site dry and not malarious, and an aspect which gives light and cheerfulness.
2. A ventilation which carries off all respiratory impurities.
3. A system of immediate and perfect sewage removal, which shall render it impossible that the air shall be contaminated from excreta.
4. A pure supply and proper removal of water; by means of which perfect cleanliness of all parts of the house can be insured.
5. A construction of the house which shall insure perfect dryness of the foundation, walls, and roof.

In other words, perfect purity and cleanliness of the air are the objects to be attained. This is the fundamental and paramount condition of healthy habitations; and it must over-ride all other considerations. After it has been attained, the architect must engraft on it the other conditions of comfort, convenience, and beauty.

The inquiries which have been made for the last thirty years in England have shown how badly the poorer classes are lodged, both in town and country, and how urgent is the necessity for improvement. Various Acts* have been passed for the purpose of improving labourers' cottages and other small dwellings, but either from the powers being insufficient, or from the difficulty of proving that a dwelling is injurious to health, unless it is in extremely bad condition, these Acts have had little effect.

Up to a certain point, there is no difficulty in insuring that a small house shall be as healthy as a large one. The site and foundations can be made as dry, the drains as well arranged, the walls and roofs be as sound, and the water supply as good as a house of much larger rental. In fact, in one respect, the houses of the poor are often superior to those of the rich, for the sewers do not open directly into the houses, and sewer air is not breathed during the night. But the difficulty in the houses of the poor is the overcrowding, and the impregnation of the walls with foul effluvia and deposits. Considerations of cost will probably always prevent our poor class of houses from having sufficient floor and cubic space. These two special difficulties must be met by improved means of warming and ventilation, and by covering the interior walls with a cement which is non-absorbent, and which can be washed. Perhaps, also, improvements in using cement, or other plans, will eventually so lessen the cost of building that larger rooms can be given for the same rental, and the poor be taught to prize the boon of an abundant allowance of air, and not seek to lessen it by crowding and underletting.

Dryness of the foundation and walls of a home is secured by draining the subsoil, 4 to 9 feet below the foundation,† and, in very wet clay soil, by paving or cementing under the entire house.‡ The walls are kept dry by being imbedded in concrete, which is brought up to the ground level, or by the insertion in the walls themselves of a waterproof course of slate, asphalt, or what is better, of ventilating vitrified thin bricks (as devised by Mr Taylor).

On wet damp soils, when a house has no cellar, the flooring ought to be raised 2 feet above the ground, and the space below should be well ventilated. In the tropics, the houses are often raised on arches 3 to 5 feet above the ground. Dryness of walls is best secured by hollow walls,§ or coating the walls with cement, which is kept painted, or with slates. Terra-cotta slabs have been used, and liquid preparations (chiefly alkaline silicates) have been brushed over the surface of brick and stone. Bricks are often extremely porous,|| and a brick wall will absorb many gallons of water.¶

Dryness of the roof should be carefully looked to in every case, as water often gets to the walls through a bad roof, and the whole house becomes damp.

The condition of the basements or cellars, if they exist, requires attention,

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* Labouring Classes Dwelling-house Act, 1866; An Act to provide better Dwellings for Artisans and Labourers, 1868; Artisan's Dwellings Act, 1875; various clauses in the different Public Health Acts.

† Even the walls of old ricketty cottages may be thoroughly dried by this means, (Rogers Field).

‡ For a good diagram of a plan for avoiding damp, see Bailey Denton's "Sanitary Engineering," Plate I. p. 56.

§ Jenning's patent Bonding Brick is a good plan for preventing moisture penetrating from the outer to the inner skin of a hollow wall. It is a hollow, vitrified brick, curved upwards at an angle of 45°, so that no water can pass along it.

|| An ordinary brick will hold about 16 oz. of water.

¶ Bricks imperfectly burned on the outside of the kiln are termed Place, or Samel, or Sandel bricks. They absorb much water. The sun-dried bricks of India are very damp, and absorb water from the air. I am not aware of the absorbing power of the bricks made by compression without burning. Many sandstones are very porous; water beats into them and rises high by capillary attraction. Lime made from chalk absorbs water. Pisé is compressed earth, and, unless covered with cement, is moist.

as the air of the house is so often drawn directly from them. They should be dry, and thoroughly well ventilated, and the house pipes, if they run down to the basement, should be always uncovered so as to be easily inspected, and any bad-fitting joint, or crack, or imperfect trap, if there be one inside the house, be at once remedied.

The carrying off of rain water, so as not to sink into the ground near the house, is a matter of importance.

The other points which are necessary to secure a healthy house, viz., good aspect and external ventilation, and sufficient room ventilation, absence of all conditions outside the house which can contaminate air entering it, a proper water supply, and due care in removing excreta, are discussed in their respective chapters.

In examining a house to discover the sources of unhealthiness, it is best to begin at the foundation, and to consider first the site and basements, then the living and sleeping rooms (as to size, cubic contents, and number of persons, and condition of walls and floors), ventilation, water supply, and plans of waste and sewer-water removal, in regular order.

The following memorandum as to the way in which engineers examine a house has been kindly given me by my friend Mr William Eassie, C.E.

## MEMORANDUM.

### *What is usually done by Sanitary Engineers when inspecting a House.*

Sanitary engineers consider that an unusual smell is generally the first evidence of something wrong, and that, traced to its source, the evil is half cured. They inspect first the drainage arrangements. If the basement generally smells offensively, they search for a leaking drain-pipe, *i.e.*, a pipe badly jointed or broken by settlement, and these will often show themselves by a dampness of the paving around. If, upon inquiry, it turns out that rats are often seen, they come to the conclusion that the house drain is in direct communication with the sewer, or some old brick barrel-drain, and therefore examine the traps and lead bends which join the drain-pipes to see if they are gnawed or faulty. If the smell arises from any particular sink or trap, it is plain to them that there is no ventilation of the drain, and more especially no disconnection between the house and the sewer, or no flap-trap at the house-drain delivery into the sewer. If a country house be under examination, a smell at the sink will, in nearly every case, be traced to an unventilated cesspool; and, in opening up the drain under the sink, in such a state of things, they will take care that a candle is not brought near, so as to cause an explosion. If the trap is full of foul black water, impregnated with sewer air, they partly account for the smell by the neglect of flushing. If the sink, and kitchen, and scullery wastes are in good order and the smell is still observable, they search the other cellar rooms, and frequently find an old floor-trap without water, broken and open to the drain. If the smell be ammoniacal in character, they trace the stable-drains and see if they lead into the same pit, and if so, argue a weak pipe on the route, especially if, as in some London mansions, the stable-drains run from the mews at the back, through the house to the front street sewer.

Should a bad persistent smell be complained of mostly in the bedroom floor, they seek for an untrapped or defective closet, a burst soil-pipe, a bad junction between the lead and the cast iron portion of the soil-pipe behind the casings, &c., or an improper connection with the drain below. They will examine how the soil-pipe is jointed there, and, if the joint be inside the house, will carefully attend to it. They will also remove the closet framing, and ascertain if any filth has overflowed and saturated the flooring, or if the safe underneath the apparatus be full of any liquid. If the smell be only occasional, they conclude that it has arisen when the closet handle has been lifted in ordinary use or to empty slops, and satisfy themselves that the soil-pipe is unventilated. They, moreover, examine the bath and lavatory waste-pipes, if they are untrapped, and if trapped by a sigmoidal bend, whether the trapping water is not always withdrawn owing to the syphon action in the full running pipe. They will trace all these waste-pipes down to the sewer, ascertain if they wrongly enter the soil-pipe, the closet-trap, or a rain water-pipe in connection with the sewer.

If the smell be perceived for the most part in the attics, and, as they consider, scarcely attributable to any of the foregoing evils, they will see whether or not the rain water pipes which terminate in the gutters, are solely acting as drain ventilators, and blowing into the dormer windows. They will also examine the cisterns of rain water, if there be any in the other portions of the attics, as very often they are full of putridity.

A slight escape of impure air from the drains may be difficult to detect, and the smell may be attributed to want of ventilation, or a complication of matters may arise from a slight escape of gas. Neither are all dangerous smells of a foul nature, as there is a close sweet smell which is even worse. Should the drains and doubtful places have been previously treated by the inmates to strongly smelling disinfectants, or the vermin killed by poison, the inspectors of nuisances will find it difficult to separate the smells. In such a case, however, they will examine the state of the ground under the basement flooring, and feel certain that there are no disused cesspools or any sewage saturation *of any sort.* They will also ascertain if there be any stoppage in the drain-pipes, by taking up a yard trap in the line of the drain march, and noting the reappearance of the lime water which they had thrown down the sinks. And invariably, after effecting a cure for any evil which had been discovered, they will leave the traps cleaned out and the drains well flushed.

Besides the drainage, they will, especially if they detect a bad and dank smell, see if it arises from the want of a damp-proof course or of a dry area, see if there be a wet soil under the basement floor, a faulty pipe inside the wall, an unsound leaden gutter on the top of the wall, or an overflowing box gutter in the roof, a leaky slatage, a porous wall, a wall too thin, and so on.

They will also keep an eye upon the condition of the ventilating arrangements, and whether the evils complained of are not mainly due to defects there. The immediate surroundings of the house will also be noted, and any nuisances estimated.

Sanitary inspectors, whilst examining into the condition of the drains, always examine the water cisterns at the same time, and discover whether the cistern which yields the drinking water supplies as well the flushing water of the closets. They will also ascertain if the overflow pipe of this cistern, or if a separate drinking water cistern, passes directly into the drain.

If the overflow pipe be syphon-trapped and the water rarely changed in the trap, or only when the ball-cock is out of order, they will point out the fallacy of such trapping; and, speaking of traps generally, they will look suspiciously on every one of them, endeavour to render them supererogatory by a thorough ventilation and disconnection of the drains.*

## SECTION II.

### HOSPITALS.

### *General Remarks.*

Of late years a great number of works (English, French, German, and American) have been written on the construction of hospitals. This has been especially owing to the celebrated "Notes on Hospitals," published by Miss Nightingale, after the Crimean war—a work the importance of which it is impossible to over-rate—and to the very useful pamphlets of Mr Roberton of Manchester. Among military writers, Robert Jackson in this, as in all other points, takes the first rank, and his observations on the construction of hospitals are conceived entirely in the spirit of the best writings of the present day. In the short space which can be given to the subject here, I can merely condense what has been best said on the subject, as applied especially to military hospitals.† In the first place, however, a few words are necessary on the general question.

Although the establishment of hospitals is a necessity, and marks the era of an advanced civilisation, it must always be remembered that if the crowding of healthy men has its danger, the bringing together within a confined area many sick persons is far more perilous. The risks of contamination of the air, and of impregnation of the materials of the building with morbid substances, are so greatly increased, that the greatest care is necessary that hospitals shall not become pest-houses, and do more harm than good. We must always remember, indeed, that a number of sick persons are merely brought together in order that medical attendance and nursing may be more easily and perfectly performed. The risks of aggregation are encountered for this reason ; otherwise it would be far better that sick persons should be separately treated, and that there should be no chance that the rapidly changing, and in many instances putrefying substances of one sick body should pass into the bodies of the neighbouring patients. There is, indeed, a continual sacrifice of life from diseases caught in, or aggravated by hospitals. The many advantages of hospitals more than counterbalance this sacrifice, but it should be the first object to lessen the chance of injury to the utmost. The risk of transference or aggravation of disease is least in the best ventilated hospitals. A great supply of air, by immediately diluting and rapidly carrying away the morbid substances evolved in such quantities from the bodies and excretions of the sick, reduces the risk to its minimum, and perhaps removes it altogether. But the supply of air must be enormous; we are not in a position to say how much, but I question whether even the large quantity of 4000 cubic feet per head per hour, now assigned by the best observers, will not be found to be far below the proper amount for the acute and febrile diseases.[*]

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* Much useful information will also be obtained from Sanitary Arrangements for Dwellings, by W. Eassie, C.E., and from Sanitary Engineering, by J. Bailey Denton, C.E.

† For fuller details, Captain Galton's work on Hospitals should be consulted. See also Five Essays on Hospital Plans, contributed for the John Hopkins Hospital scheme (Wood and Co., New York); Report on the Manchester Royal Infirmary, by J. Netten Radcliff, Esq.; Reports on St. Mary's Hospital, Paddington, by F. de Chaumont, M.D.; chapter in Roth. and Lex, Milit. Gesundheitspflege; paper in the Practitioner, March 1877.

The causes of the greater contamination of the air of hospitals are these :—

1. More organic effluvia are given off from the bodies and excretions of sick men. These are only removed by the most complete ventilation.

2. The medical and surgical management of the sick necessarily often exposes to the air excretions, dressings, foul poultices, soiled clothes, &c., and the amount of substances thus added to the air is by no means inconsiderable, even with the best management.

3. The walls and floors of hospitals absorb organic matters and retain them obstinately, so that in some cases of repeated attacks of hospital gangrene in a ward it has been found necessary to destroy even the whole wall. Continual drippings on the floor of substances which soak into the boards and through crevices, and collect under the floor, also occur, and thus collections exist of putrefying matters which constantly contaminate the air.

4. The bedding and furniture also absorb organic substances, and are a great cause of insalubrity.

5. Till very recently, even in the best hospitals, the water-closets and urinals were badly arranged, and air passed from these places into the wards.

In addition to the necessary amount to dilute and remove these substances, the freest supply of air is also now known to be a curative means of the highest moment ; in the cases of the febrile diseases, both specific and symptomatic, it is indeed the first essential of treatment; sometimes, especially in typhus and smallpox, it even lessens duration, and in many cases it renders convalescence shorter.[†]

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[*] In my paper, On the Theory of Ventilation, (Proceedings of the Royal Society 1875), I have shown that the smell of organic matter becomes perceptible in hospitals when the carbonic acid exceeds the external air ratio by 0·166 per 1000, whereas in barracks it is not perceived until it has passed 0·208 per 1000 ; so that, if 3000 cubic feet be the minimum per hour for health, not less than 4000 must be adopted for even ordinary cases of disease, and as much more as can be obtained for surgical or febrile diseases. (F. de C.)

[†] The effect of a great supply of air on some diseases is marvellous, and the subject is so important that a few examples may be quoted. The experience of the fevers in the force assembled at Cork in 1795 ; of the spotted typhus of 1814 at Paris, when it was noticed with astonishment that the cases placed (with great fear of the result) in the abbattoir of Montfaucon (one of the highest and most breezy parts of Paris), did infinitely better than the patients in the regular hospitals ; and the analogous case of the Irish fever of 1847–48, when cases left in the open air

There can, I believe, be no doubt, that the necessity for an unlimited supply of air is the cardinal consideration in the erection of hospitals, and, in fact, must govern the construction of the buildings. For many diseases, especially the acute, the merest hovels with plenty of air are better than the most costly hospitals without it. What ill-judged humanity it is to overcrowd febrile patients into a building, merely because it is called an hospital, when the very fact of the overcrowding lessens or even destroys its usefulness. In times of war, it should never be forgotten by medical officers that the

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and in the rudest sheds recovered better than those patients who had all the advantages of the fixed establishments, can be paralleled by many other instances. A case full of instruction for the army surgeon was recorded 100 years ago by Brocklesby, physician to the army in 1764.[*]

"In October 1758, a greater number of sick were landed out of the transports on the Isle of Wight than all the spare outhouses, barns, and empty cottages which could be procured for money or the sake of humanity at Newport, were capable of containing. In this distress, some gentlemen of the hospital proposed to erect a temporary shed, with deal boards, upon the open forest, and to have it thatched over with a coat of new straw, thick enough to keep out wind and rain, and capacious enough to hold 120 patients or upwards; for doing which, and the use of the boards, the country workmen exacted forty pounds. Although the hovel was finished in a fashion the most slovenly, and apparently inadequate to the end proposed, upon trial it was found that, notwithstanding much extraordinary cold, as well as moisture, which the sick there lodged had suffered, remarkably fewer died of the same diseases, though treated with the same medicines and the same general regimen, than died anywhere else; and all the convalescents recovered much sooner than they did in any of the warmer and closer huts and barns hired round Newport, where fires, and apparently better accommodations of every sort, could be provided for them." (Pp. 66, 67.)

He gives another instance afterwards.

In making these rough sheds with wattle, Brocklesby incidentally mentions two points of importance:—1. The removing from time to time the ground from the surface, as it gets impregnated with all sorts of things. 2. The building of a large entrance porch, sheltered over head (but not at the sides?), into which the convalescent men can creep, to get as much as possible into the open air, and also to eat their meals in it.

Another old army surgeon[†] records an analogous case. Donald Munro says that Dr Hume told him, that in 1755, some of the men-of-war carried out to North America a malignant jail fever, brought by impressed men. The fever continued to spread while at sea; but at Halifax the sick "were lodged in tents, or in very old shattered houses that admitted the air very freely, which put a *sudden* and effectual stop to this disorder."

The same facts were before clearly pointed out by Pringle, who witnessed the loss occurring in military hospitals when spotted typhus once gained a footing; and they were also fully understood by Sir James M'Grigor in the Peninsular war. As far as spotted typhus is concerned, no evidence is necessary to convince us that patients must be treated with an absolutely unlimited supply of air; and with respect to some other diseases, the remarkable experience of the Austrian army surgeons for the last few years shows that the same rule applies to typhoid fever, small-pox, pyæmia, hospital gangrene, and wounds. Since 1854, the sick of the Austrian army have been largely treated, during eight or nine months every year, in well-ventilated tents in preference to fixed hospitals. The result has been most remarkable; disease was prevented from spreading, and patients got well much more rapidly than in the apparently more comfortable permanent hospitals. For particulars, the Report on Hygiene by the author, in the Army Medical Report for 1862, can be referred to; some of the most important facts are given under the head of Field Hospitals in War. In Dr Massey's paper in the Army Medical Department Report, vol. xi. p. 229, is an able statement of facts of a similar kind.

In Germany many of the large hospitals have now small wooden buildings (barrack-hospitals) in adjoining hospital enclosures, where all the worst surgical cases are treated.

An analogous experience has led some of our best surgeons (Sir James Paget, for example) to believe that in pyæmia a patient should be treated almost in the open air.

In yellow fever the same rule holds good; and to show how early this was appreciated, I subjoin a quotation from Lind.

Lind[‡] quotes from "a very sensible man, who resided long in Jamaica."

"I have often observed the poor seamen in the merchant service to recover from the yellow fever solely by having the benefit of a free and constant admission of the cool sea air into a ship anchored at a distance from the shore, where they lay utterly destitute of every assistance in sickness, and even of common necessaries, having nothing but cold water to drink, and not so much as a bed to lie upon; while gentlemen newly arrived from England, by being shut up in small, close, suffocating chambers at Kingston or Port-Royal, expired, with their whole mass of blood dissolved, flowing from every pore—the stifling heat of their room having produced a state of universal putrefaction in the body, even before death."

[*] Economical and Medical Observations from the year 1758 to 1763, by R. Brocklesby, 1764.

[†] Donald Munro, vol. i. p. 269.

[‡] On Diseases of Europeans in Hot Climates, p. 215.

rudest shed, the slightest covering, which will protect from the weather, is better than the easy plan so often suggested and acted on, of putting the beds a little closer together.

The recognition that the ample supply of pure air is the first essential of a good hospital, led Miss Nightingale to advocate with so much energy and success the view which may be embodied in the two following rules :—

1. The sick should be distributed over as large an area as possible, and each sick man should be as far removed as possible from his neighbour.

2. The sick should be placed in small detached and perfectly ventilated buildings, so that there is no great number of persons in one building, and there shall be no possibility of the polluted air of one ward passing into another.

### *How is this perfect Purity of Air to be secured?*

This is a matter partly of construction, partly of superintendence.

(*a*) There should be detached buildings, so disposed as to get the freest air and the greatest light. They should be at considerable distances apart, so that 1000 sick should be spread like a village ; and in the wards, each man ought to have not less than 100, if possible, 120, feet of superficial, and from 1500 to 2000 feet of cubic space.* With detached buildings, the size of an hospital, as pointed out by Miss Nightingale, is dependent merely on the facility of administration. When the hospitals consist of a single building the smallest hospitals are the best.

(*b*) The ventilation should be natural, *i.e.*, dependent on the movement of the outer air, and on inequalities of weight of the external and internal air. The reason of this is, that a much more efficient ventilation can be obtained at a cheaper cost than by any artificial means. Also, by means of open doors and windows, we can obtain at any moment any amount of ventilation in a special ward, whereas local alterations of this kind are not possible in any artificial system. The amount of air, also, which any artificial system can cheaply give is comparatively limited. The amount of air should be restricted only by the necessity of not allowing its movement to be too perceptible.

The best arrangements for natural ventilation for hospitals appear to me to be these—1*st*, Opposite windows reaching nearly to the ceiling, on the sides of a ward (not wider than 24 feet, and containing only two rows of beds), and a large end window. 2*d*, Additional openings, to secure, as far as possible, a vertical movement of the air from below upwards; and this, I believe, will be best accomplished as follows :—†

A tube opening at once to the external air should run transversely along the floor of the ward to each bed, and should end in a box placed under the bed, and provided with openings at the top and sides, which can be more or less closed. In the box, coils of hot-water pipes should be introduced to warm the air when necessary. The area of the tube should not be less than 72 square inches to each bed ; and the area of the openings in the box at least four times larger. The fresh air, warmed to any degree, and moistened, if necessary, by placing wet cloths in the box, or medicated by placing chlorine, iodine, or other substances, will then pass under each bed, and ventilate that space so often left unaired ; and then, ascending round the sides of the bed, will at once dilute and carry up the products of respiration and transpiration to the ceiling. It would, I presume, be a simple matter so to arrange the hot-water pipes as to be able to cut off all or some of the pipes under a particular bed from the hot-water current if desired, and so to give a fever patient air of any temperature, from cold to hot, desired by the physician. In the low and exhausted stages of fever warm air is often desirable. By this simple plan, it seems to me we could deal more effectually with the atmosphere round our patients, as to warmth, dryness, humidity, and medication, than by any other. At the same time, the open fire-place and chimney, and the open doors and windows, might be preserved.*

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* See page 147 for the discussion on this point.

† A plan similar to this has been devised by Dr S. Hale, and adopted in some of the Australian hospitals. It is an excellent arrangement, but seems rather unnecessarily complicated by taking the air under the floor, and elevating the beds on a dais.

For the exit of the foul air, channels in the ridge should be provided, warmed by gas if possible, as pointed out in the chapter on VENTILATION.

To facilitate this system of ventilation, it is desirable to have the buildings one storied only ; but it can be applied with two stories. Only then the discharge tubes must be placed at the sides, and run up in the thickness of the walls.†

But not only should there be good ventilation, but the wards ought to be every year empty for two or three weeks, and during the time thoroughly exposed to the air, every door and window being open.

(*c*) The strictest rules should be laid down with regard to the immediate removal from the wards of all excreta, dirty dressings, foul linen, &c.

Nothing that can possibly give off anything to the air should be allowed to remain a single moment. Dressings of foul wounds should be sprinkled with deodorants, and charcoal bags suspended round the bed.

(*d*) The walls should be of impermeable material. Cements of different kinds are now used, especially Parian; large slabs of properly coloured tiles, joined by a good cement, and good Portland cement well painted would, however, be better. Parian cracks and spaces form behind it. Ceilings should be either cemented or frequently limewashed. Great care should be taken with the floors. On the whole, good oak laid on concrete seems the best material; but the joinings should be perfect, so that no fluid may pass through and collect below the floor. Possibly it might be well to cover the floor with a good oil-cloth, or material of the like kind, which would prevent substances from sinking into the boards, and would lessen the necessity of washing the floors, but might be itself removed, and frequently washed. The practice of waxing and dry-rubbing the floors, and other similar plans, is intended to answer the same purpose. Dr Langstaff, of Southampton, strongly recommends paraffin. The paraffin is melted and then poured on the floor, and ironed into it with a box-iron, heated from the interior by burning charcoal; it penetrates about a quarter of an inch into the wood. The excess of paraffin is scraped off, and the floor is brushed with a hard brush; a little paraffin in turpentine is then put on, and the flooring is good for years.

(*e*) The furniture in a ward should be reduced to the minimum; and, as far as possible, everything should be of iron. The bedding should also be reduced in size, as much as it can be. Thick mattresses should be discarded, and thin mattresses, made easy and comfortable by being placed on springs, employed.‡ The material for mattresses should be horse-hair (18 ℔ weight to each mattress), or coir fibre, which, on the whole, are least absorbent. Straw, which absorbs very little, is bulky, and is said to be cold.

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* The introduction of vertical tubes is also useful, as giving the air an upward direction and allowing a considerable supply without draughts.

† When the ceiling is flat the outlets may be advantageously placed at the sides close to the ceiling, but with a one-storied or upper ward an open roof is better.

‡ The wire mattress bedstead, as arranged by Dr Reed, in use in the Manchester Royal Infirmary and made by Messrs Chorlton & Dugdale, seems an excellent and very comfortable form.

All flock and woollen mattresses should be discarded. Blankets and coverlets should be white or yellowish in colour, and should be frequently thoroughly aired, fumigated, and washed.

(*f*) The arrangement of the water-closets and urinals is a matter of the greatest moment. Every ward should have a urinal, so that the common practice of retaining urine in the utensils may be discontinued. If the urine is kept for medical inspection, it should be in closed vessels. The removal of excreta must be by water. In hospitals, nothing else can be depended upon, as regards certainty and rapidity. The best arrangement for closets is not the handle and plug, which very feeble patients will not lift; but a self-acting water supply connected with the door, and flowing when it is opened. This plan is better than the self-acting spring seat, which is not always easily depressed by a thin patient; and also, by leaving the door open, it gives us the means of pouring in any quantity of water, and of thoroughly flushing the pan and pipe. The closets are best arranged in nearly detached lobbies, at one end of the ward, and separated from it by a thorough cross ventilation, as shown in the plan which is copied from Miss Nightingale's work.*

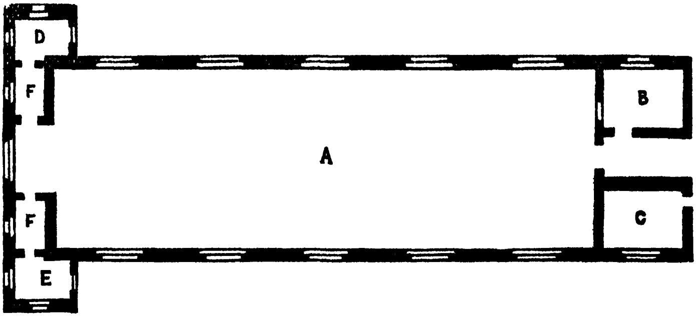

Fig. 76—Ward for 20 Ward-beds.

A. Ward.
B. Nurse's room, with Ward-window.
C. Scullery.
D. Water-closet and Ward-sink.
E. Bath-room and Ablution-room.
F. Ventilated lobbies.

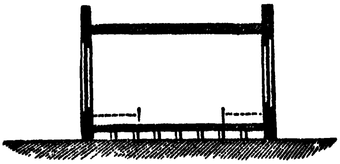

Fig. 77.
Section of Ward to show the Bed.

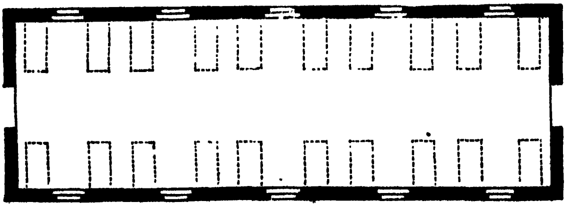

Fig. 78.—Drawing to show Beds and Windows.

In this way, provided the site of the hospital is originally well chosen, perfect purity of air can be obtained, and the first requisite of a good hospital is secured.

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* Dr Buchanan has suggested a plan of vertical ventilation in the vestibule, in cases where cross ventilation is not available. This, of course, need not be in a new building, although it might be useful in the adaptation of an existing one. The addition of a slop sink, for the emptying of bed-pans, &c., would also be useful.

The warming of the air of Hospitals is discussed in the chapter on WARMING.

Next to the supply of pure air, and to the measures for preventing contamination (which embrace construction, ventilation, cleanliness, and latrine arrangements), come the arrangements for medical treatment.

Medical treatment includes—

1. *Supply of Food.*—The diet of the sick is now becoming a matter of scientific precision; and it is probable that every year greater and greater importance will be attached to it. Hence the necessity of a perfect central kitchen, and of means for the rapid supply of food at all times. There is more difficulty in doing this than at first appears, as the central kitchen cannot supply everything; and yet there must be no cooking in the wards, or even near them, as the time of the attendants should be occupied in other ways. Probably, the best arrangement is to have hot closets close to the wards, where the food sent from the kitchen can be kept warm, and ready for use at all hours of the day and night.

2. *The Supply of Water.*—Hot and cold water must be supplied everywhere, and baths of all kinds should be available. The supply of water for all purposes should be 40 to 50 gallons per head daily.

3. *The Supply of Drugs and Apparatus.*—The chief point is to economise the time of attendants, and to enable drugs and apparatus to be procured without delay when needed.

4. *The Nursing and Attendance, including the Supply of Clean Linen, &c.*—The time and labour of the attendants should be expended, as far as possible, in nursing, and not in other duties. Every contrivance to save labour and cleaning should therefore be employed. Lifts, shafts, tramways, and speaking-tubes to economise time; wards arranged so as to allow the attendants a view of every patient; wards not too large nor too small, for Miss Nightingale has conclusively shown that wards of from 20 to 32 beds are best suited for economy of service.

5. *Means of Open-air Exercise for Patients.*—This ought properly to be considered as medical treatment. As soon as a patient can get out of his ward into the open air he should do so; therefore, open verandahs on the sunny sides of the wards, and sheltered gardens, are most important. For the same reason hospitals of one story are best,* as the patients easily get out; if of two stories the stairs should be shallow.

6. In addition to all these, the supply of air medicated with gases, or fine powders, or various amounts of watery vapour, is a mode of treatment which is sure to become more common in certain diseases, and special wards will have to be provided for these remedies.

The parts of a military hospital are—†

*Patients' Rooms, Wards,* and *Day-rooms,* if possible; the wards of two sizes; large, *i.e.*, from 20 to 32 beds; and small, for one or two patients. It is desirable to have the small wards not close to the large ones, but at some little distance. Attached to the wards are attendants' rooms, scullery, bath

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* I had never properly estimated the importance of patients getting into the air, and the desirability of one-storied buildings for this purpose, till I served at Renkioi in Turkey during the Crimean war. The hospital was composed of one-storied wooden houses connected by an open corridor. As soon as a man could crawl he always got into the corridor or between the houses, and the good effects were manifest. Some of the medical officers had their patients' beds carried out into the corridor when the men could not walk. In the winter greatcoats were provided for the men to put on, and they were then encouraged to go into the corridor.

† Hospital space is to be provided for 10 per cent. of the force. Lately, since the health of the army has been so much improved on home service, it has been proposed to reduce it to 7 per cent., but it would appear desirable always to have a large hospital space for emergencies and for war.

The Director-General is consulted when a fresh hospital is built.

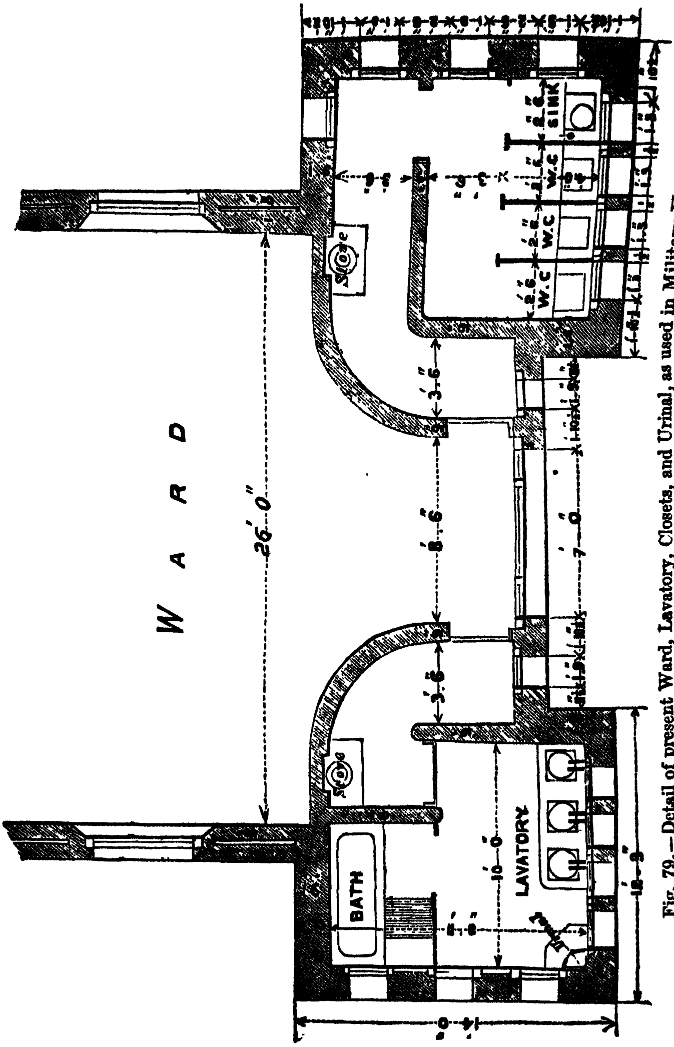

Fig. 79.—Detail of present Ward, Lavatory, Closets, and Urinal, as used in Military Hospitals (from Miss Nightingale's book).

The Surgeons-General and Deputy Surgeons-General are ordered to inspect the drainage, ventilation, water supply, water-closets, latrines, urinals, and sinks of every hospital, and to see that the warming and lighting are sufficient, also that the number in hospital is not over regulation; that the excreta of the sick are promptly removed from the wards; that cleanliness, cooking, &c., are properly attended to; and that the vicinity of the hospital is in good condition, and the hospital itself in good repair.

In general hospitals a sanitary officer is to be appointed; in station hospitals the medical officer is the sanitary officer, and his duties as to inspection are explicitly laid down.

If any building is selected as a temporary hospital, the sanitary officer, or medical officer in charge, is ordered to inspect it, and to recommend such alterations as are necessary.

Convalescent wards are to be provided when practicable.

and ablution rooms, small storeroom, urinal, closets (one seat to every eight men.)

*Operating-room—Dead-house—Administration.*—Surgeons' rooms; case-book and instrument room; offices and officers' rooms.

*Pharmacy.*—Dispensary; store-room; dispenser's room.

*Culinary.*—Store-room; wine and beer room; larder and meat room; kitchen; room for arranging diets; scullery, cook's room.

*Washing.*—Washhouse; dirty linen store; baking and fumigating-room; cleaning-room for mattresses.

*Steward's Department.*—Offices, furniture, linen, utensil, and pack stores; rooms for cleaning.

The amount of storage room is, for an hospital of 100 sick—

| | | | |
|---|---|---|---|
| Bedding and store | = 200 square feet. | Fuel store | = 250 square feet. |
| Clothing store | = 100 „ | Foul linen store | = 120 „ |
| Utensil store | = 160–200 „ | Pack store | = 200 „ |
| Provision store | = 100 „ | (In military hospitals.) | |

The above drawing shows the arrangement of the closets and lavatory in a military hospital.

The two following plans show the arrangement of the Lariboisiére Hospital in Paris,* which circumstances have made the type of the so-called block or pavilion plan; and of the Herbert Hospital, which is the best military hospital in this country, or perhaps anywhere.

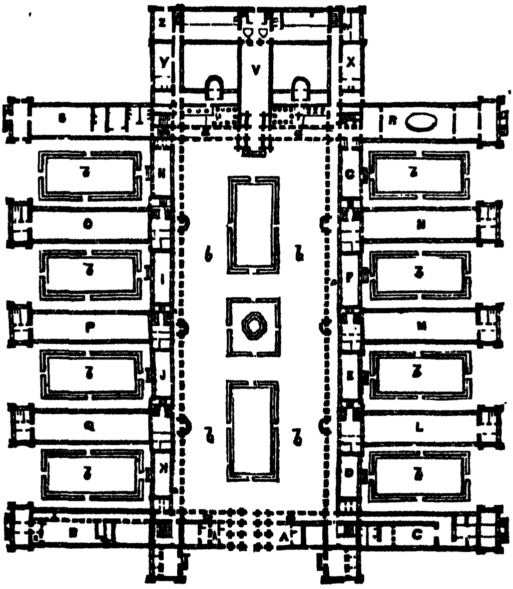

Fig. 80.—Lariboisiére Hospital at Paris.

The Herbert Hospital at Woolwich consists of four double and three single pavilions of two floors each, all raised on basements. There is a convalescent's day-room in the centre pavilion. The administration is in a separate block in front. The axis of the wards is a little to the east of north. There is a corridor in the basement, through which the food, medicines, coals, &c., are conveyed, and then, by a series of lifts, elevated to the wards. The terraces on the corridor afford easy means of open-air exercise for the patients in the upper ward. The wards are warmed by two central open fire-places, with descending flues, round which are air-passages, so that the entering air is warmed. The floors are iron beams, filled in with concrete, and covered with oak boarding.*

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* The new Hôtel-Dieu, just completed, is on the same general plan.

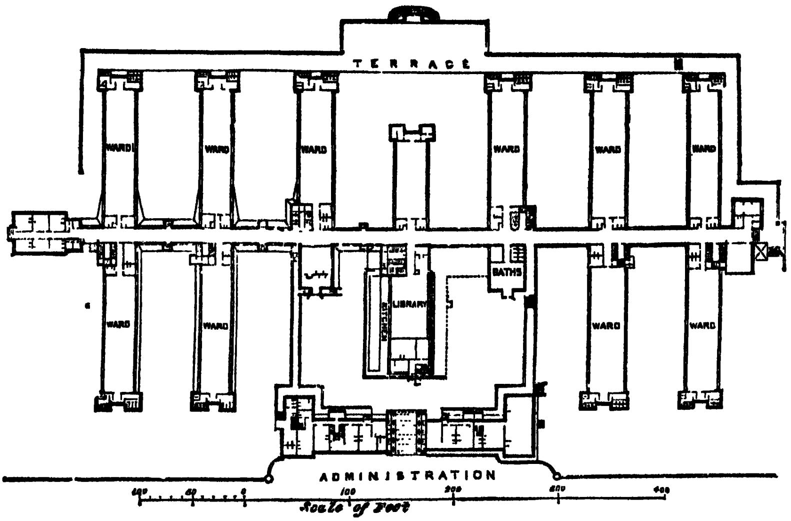

Fig. 81.—Ground Plan of the Herbert Hospital, Woolwich (from Miss Nightingale's book.)

## *Hospitals in the Tropics.*

The Barrack and Hospital Commission, in carrying out the plans of the Royal Indian Sanitary Commission, suggest† for each sick man—

Superficial area = 100 square feet, up to 120 in unhealthy districts.

Cubical space = 1500 feet, or, in unhealthy districts, 2000 feet.

It is also directed that hospitals should consist of two divisions—1st, for sick; and 2d, for convalescents. This latter division to hold 25 per cent. of the total hospital inmates.

Each hospital is to be built in blocks, to consist of two floors, the sick and convalescents to sleep on the upper floors only; each block to hold only 20 to 24 beds.

The principles and details are, in fact, identical with those already ordered for the home stations.

## *Hospitals for Infectious Diseases.*

Fever and small-pox hospitals have been long established in many large English towns; but within the last few years it has become usual for all towns of any size to put up some temporary hospitals during an outbreak of cholera, small-pox, relapsing fever, and typhus, and to remove persons ill with these diseases, at once from their dwellings. In this way, if there is early discovery of the cases, the chances of spread of the disease are greatly lessened.

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* The arrangement of the Pavilions may be varied in many ways; for different forms of arrangement see the works already cited.

† *Op. cit.* p. 27.

The Medical Department of the Privy Council issued a Memorandum in 1872,* pointing out that power is given under the 37th section of the Sanitary Act, 1866,† to the local board, improvement commissioners, town council, or vestry, to provide "hospitals or temporary places for the reception of the sick." It is pointed out that villages should have the means of accommodating instantly four cases of infectious disease in at least two separate rooms, and it is considered that a good cottage would answer this purpose. In towns a permanent provision is advised to be made, and the following suggestions are made :—The situation to be convenient; ward cubic space, 2000 feet per head; ward floor space per head 144 square feet; good provision for ventilation; precautions against entrance of foul air (as from privies or sinks); warming in winter to 60° Fahr.; keeping cool in summer; means of disposal of excrements and slops, and for cleaning and disinfecting linen.

For temporary emergencies, tents (army hospital marquees) are recommended, or huts are advised. The huts are described at some length, and plans are given of the huts and of the arrangement. As these are very similar to those used by the army in war, reference is made to that section.

(For Hospitals in Time of War, see Book II.)

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* Memorandum on Hospital Accommodation to be given by Local Authorities (signed John Simon, 8th July 1872).

† Now under the 131st and following clauses of the Public Health Act of 1875.

# CHAPTER X.

# REMOVAL OF EXCRETA.

We have seen that a regular supply of pure air—in other words, efficient ventilation—is required to remove the excreta of the lungs and the volatile products of the skin. The solid and fluid excreta from the bowels and the kidneys ought to be as rapidly and as completely removed as the gaseous impurities.

It is highly probable that to barbarous and inefficient modes of removing the excreta of men and of animals we must partly trace the great prevalence of disease in the middle ages, and there is no doubt that many of the diseases now prevailing in our large towns are owing to the same cause.

When men live in thinly-populated countries, following, as they will then do, an agricultural or nomade life, they will not experience the consequences of insufficient removal of excreta. The sewage matter returns at once to that great deodoriser the soil, and fertilising it, becomes a benefit to man, and not a danger. It is only when men collect in communities that the disposal of excreta becomes a matter literally of life and death, and before it can be settled the utmost skill and energy of a people may be taxed.

The question of the proper mode of disposal of sewage has been somewhat perplexed by not keeping apart two separate considerations. The object of the physician is to remove as rapidly as possible all excreta from dwellings, so that neither air, water, nor soil shall be made impure. The agriculturist wishes to obtain from the sewage its fertilising powers. It is not easy to satisfy both parties, but it will probably be conceded that safety is the first thing to be sought, and that profit must come afterwards.

## SECTION I.

## AMOUNT AND PRODUCTS OF THE SOLID AND FLUID EXCRETA.

### *Amount of the solid and fluid Excreta.*

The amount of the bowel and kidney excreta vary in different persons and with different modes of life. On an average, in Europe, the daily solid excreta are about 4 ounces by weight, and the daily fluid excreta 50 ounces by measure for each male adult. Women and children pass rather less. Vegetable pass more solid excreta than animal feeders, but this is chiefly owing to a large proportion of water.* Taking all ages and both sexes into consideration, we may estimate the daily amount per head of population in Europe at 2½ ounces of fæcal, and 40 ounces of urinary discharge. A population of 1000 persons would thus pass daily 156 ℔ of solids and 260 gallons of urine, or in a year 25 tons of fæces and 91,250 gallons (14,646 cubic feet) of urine. Letheby gives the mean amount per head as 2·784 ounces of fæces and 31·851 ounces of urine. In a mixed population of 1000 persons of different sexes and ages, Letheby has calculated that the daily discharge of the whole town will be 2266 ℔ avoir. of urine and 177·5 ℔ of fæces.

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* Mr Fawcus's experiments on Bengalee prisoners give an average bowel excretion of 12 ounces, and in Bombay Dr Hewlett found the alvine discharges to be quite as large.

Frankland estimates the mean daily amount per head as 3 ounces of fæces, and nearly 40 ounces by measure of urine. In adult males the quantity of nitrogen daily discharged by the bowels and kidneys amounts to from 250 to 306 grains, representing 304 and 372 grains of ammonia. Taking the whole population, however, the amount must be considerably less than this. I calculate it as 153 grains of nitrogen, and Letheby gives it as 155·8 grains, or from 186 to 189 grains of ammonia, *i.e.*, the mean excretion of all the population is very nearly half the excretion of the adult male.

### *Decomposition of Sewage Matter.*

Fresh healthy fæcal matter from persons on mixed diet, unmixed with urine, has an acid reaction, and this it retains for a considerable time; it then becomes alkaline from ammonia. If free from urine, it usually decomposes slowly, and in hot weather often dries on the surface, and subsequently changes but little for some time. The urine, when unmixed with fæcal matter, also retains its natural acidity, for a variable number of days, sometimes three or four; sometimes eight or ten, or even longer, and then becomes alkaline from ureal decomposition. When the fæces and urine are mixed, the formation of ammonium carbonate from ureal decomposition is much more rapid; the solid excreta seem to have the same sort of action as the bladder mucus, and the mixed excreta become alkaline in twenty-four hours, while the separate excreta are still acid. And in its turn the presence of the urine seems to aid the decomposition of the solid matter, or this may be perhaps from the effect of the fluid, as pure water seems to act almost as rapidly as urine in this respect. Pappenheim* states that the absorption of oxygen by the fæces is greatly increased when urine is added. When the solid excreta and urine are left for two or three weeks, the mixture becomes usually extremely viscid, and this occurs, though to a less extent, when an equal quantity of pure water takes the place of urine. The viscidity is prevented by carbolic acid.

When the solid excreta (unmixed with urine) begin to decompose, they give out very fœtid substances, which are no doubt organic; sulphuretted hydrogen is seldom detected, at any rate by the common plan of suspending paper soaked in lead solution above the decomposing mass. When heated, a large quantity of gas is disengaged, which is inflammable, and consists in great measure of carburetted hydrogen. When (instead of being dry) urine is present, ammonia and fœtid organic matters are disengaged in large quantity. When water is also present, and if the temperature of the air is not too low, not only organic matters but gases are given out, consisting of light carburetted hydrogen, nitrogen, and carbonic acid. Sulphuretted hydrogen can be also disengaged by heat, and is almost always found in the liquid, usually in combination with ammonia, from which it is sometimes liberated and then passes into the air.

### *Composition of the Air in Cesspools and Sewers* (see page 107).

### *Effects of Sewage Effluvia on Health* (see page 125).

## SECTION II.

## METHODS OF REMOVAL OF EXCRETA.

While all will agree in the necessity of the immediate removal of excreta from dwellings, the best modes of doing so are by no means settled. It is unfortunate that some warmth of controversy has been introduced into the discussion on this point, and that a feeling of partisanship has arisen. The fact is that several methods of removing sewage are applicable in different circumstances, and their relative amounts of utility depend entirely on the condition of the particular place.

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* Handb. der San. Pol. 2d edit. band i. p. 72.

The different plans may be conveniently divided into—*

1. The water method.
2. The dry methods.

Before noticing these plans, it will be convenient to make a few general observations on sewers.

## SEWERS.

Sewers are conduits employed to remove waste water and waste products suspended in water from houses, or to carry away rain. Among the waste products may be the solid and liquid excreta of men and animals, or the refuse of trade and factory operations. Or sewers may be used merely for the conveyance of dirty house water, without the admixture of excreta or trade refuse.

It is quite impossible that any town or even any single large house can be properly freed of its waste house water without sewers, and in a more or less perfect condition, they are to be found not only in all modern, but in most ancient cities. Originally, no doubt, they were mere surface channels, as they are still in many towns; but for the sake of appearance and inoffensiveness, the custom must have soon arisen of placing them underground, nor in modern towns could they now be arranged otherwise. In some large towns there are even hundreds of miles of sewers constructed often with great skill and science, and they serve in some instance as the channels not only for rain, but for natural streams which have been enclosed.

The sewers form thus in the subsoil of towns a vast network of tubes, connecting every house, and converging to a common outlet where their contents may be discharged.

In some towns the sewers carry away none of the solid excreta, though probably urine enters in all cases. In most towns, however, solid excreta in greater or less quantity enter, owing especially to the prevalent use of water-closets, or to the drainage of middens and manure heaps.

Whether the solid excreta pass in or not, the liquid in the sewers must always contain either suspended or dissolved animal and vegetable matters derived from the refuse of houses. It is generally warmer than the water of streams, and is of no constant composition; sometimes it is very turbid, and highly impure; in other cases it is hardly more impure than the water of surface wells. The suspended matters are, however, generally in larger proportion than the dissolved.

In some cases the sewer water is in greater amount than the water supplied to the town and the rainfall together. This arises from the subsoil water finding its way into the sewers.

One ton of London or Rugby sewage contains only from 2 ℔ to 3 ℔ of solid matter (Lawes).†

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* Dr Corfield's work (A Digest of Facts Relating to the Treatment and Utilisation of Sewage, by W. H. Corfield, 2d edit. 1871) will be found to give a good summary of this subject. See also Report of a Committee appointed by the President of the Local Government Board to inquire into the several modes of treating Town Sewage, London, Eyre and Spottiswoode, 1876.

† For the composition of sewer water see Way, Second Report of Common Sewage of Towns,

The average composition of sewer water in towns with water-closets is, organic matter, 27·72; nitrogen, 6·21; phosphoric acid, 1·57; potash, 2·03 grains per gallon.*

The Rivers Pollution Commissioners give 7·28 grains of organic nitrogen per 100,000 parts, or 5·41 grains per gallon; the mean amount of ammonia is 6·703 per 100,000, or 4·695 grains per gallon.

Under the microscope, sewer water contains various dead decaying matters, and in addition multitudes of Bacteria and amœbiform bodies, as well as some ciliated infusoria, especially Paramecia. Fungi (spores and mycelium) are seen, but there are few Diatoms or Desmids, and not many of the higher animals, such as rotifera.

A controversy is still going on, whether the solid excreta ought to be admitted into the sewers. The point is virtually practically decided in many towns in this country by the general use of water-closets, which cannot now in these towns be superseded by any plan yet proposed. It is, however, quite an open question, whether, if all the arrangements could be commenced *de novo*, the admission of the solid excreta would be proper.

The arguments for and against this view will presently be stated.

Whether the solid excreta are allowed to pass in or not, it is clear that the dirty water of the sewers must in some way be disposed of. It is in every case more or less impure, containing animal and vegetable substances in a state of commencing decay, which passes readily into putrefaction. The readiest mode of getting rid of it is to pass it into streams, where it is at once subjected to the influence of a large body of water, and where the solid matters either become slowly oxidised, or form food for fishes or water plants, or subside. Although from an early period streams were thus contaminated and their water originally pure was thus rendered unfit for use, it is only lately that a strong opposition has arisen to the discharge into streams. This is owing partly to the greater pollution and nuisance caused by the more common use of water-closets and the largely increasing trade of the country, which causes more refuse to be sent in, and partly to the evidence which has been lately brought forward of the diseases which are caused by drinking water made impure in this way. To prevent the nuisance and danger caused by the pollution of streams, many actions at law have been brought, and in some cases special Acts of Parliament have forbidden the discharge of sewer water into certain rivers until after efficient purification. The Rivers Pollution Act of 1876, now deals with the question, its provisions having come into operation on the 15th Aug. 1877.

Up to a certain point, there would probably be a general agreement as to the principle on which this difficult question should be dealt with. Animal substances in a state of decay can be best prevented from contaminating the air, the soil, or the water of streams, by imitating the operations of nature. In the endless cycle of physical change, decaying animal matters are the natural food of plants, and plants again form the food of animals.

It so happens that, with the exception of some mineral trades, the waste products of which are hurtful to agriculture, many of the substances contained in the sewer water of our towns are adapted for the food of plants, and we seem on sure ground when we decide that it must be correct to submit these matters to the action of plant life, and thus to convert them from dangerous impurities into wholesome food.

The difficulty is, however, with the application of the principle, and at the

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1861, p. 69, *et seq.*; Letheby, The Sewage Question, 1872, p. 135; Report on Town Sewage, 1876.

* Letheby, *op. cit.* p. 138.

present moment there is the utmost diversity of opinion on this point. It seems, however, that we may divide the opinions into two classes. According to one opinion, the proper mode is to bring the waste water of towns, when it contains fertilising matters, at once to the ground, and after the arrest of substances which may block the pipes, to pour it over the land in such a way as may be best adapted to free it from its impurities, and to bring it most rapidly and efficiently under the influence of growing plants.

The other opinion objects to this course on two grounds; first, that the substances are not brought to the ground on the most convenient form for agriculture, and also that the plan entails evils of its own, arising from the immense quantity of water brought upon the land and from the difficulty of efficient management. The advocates of this second view would, therefore, use some plan of separating the impurities of the water, and would then apply them in a solid form to the land, or use them for some other purpose, as in General Scott's plan of adding the materials for cement and then making this substance. The purified water would then be filtered through land, or passed into streams without further treatment.

In the case of the sewage water containing materials not adapted for agriculture, both parties would deal with it in the same way, viz., purify it by chemical agencies or filtration, and then allow the water to flow off into streams, while the solid products would be disposed of in the most convenient way.

These general views apply to any sewer water, whether it contains solid excreta or not, although if these excreta can be perfectly excluded the sewer water is less offensive. It has hitherto been often poured into streams without previous purification, though now this practice is prohibited by law.

The sewers of a town are for the most part used also to carry off the rainfall, and, indeed, before the introduction of water-closets, they were used only for this purpose, and for taking away the slop and sink water of houses. In countries with heavy rainfall, and in this country in certain cases, the rainfall channels are distinct from the sewers, and the outfalls may be in an entirely different direction. This is sometimes called the "separate system."

## REMOVAL OF EXCRETA BY WATER.

This is the cleanest, the readiest, the quickest, and in many cases the most inexpensive method. The water supplied for domestic purposes, and which has possibly been raised to some height by steam or horse power, gives at once a motive force at the cheapest rate; while, as channels must necessarily be made for the conveyance away of the waste and dirty water, which has been used for domestic purposes, they can be used with a little alteration for excreta also. It would be a waste of economy to allow this water to pass off without applying the force which has been accumulated in it for another purpose.

But if this is obvious, it is no less so that certain conditions of success must be present, without which this plan, so good in principle, may utterly fail. These conditions are, that there shall be a good supply of water, good sewers, ventilation, a proper outfall, and means of disposing of the sewer water. If these conditions cannot be united, we ought not to disguise the fact that sewers may give rise to no inconsiderable dangers. For what are they? They are underground tubes, connecting houses, and allowing possibly, not merely accumulation of excreta, but a ready transference of gases and organic molecules from house to house, and occasionally also causing, by bursting, contamination of the ground, and poisoning of the water supply. And all these dangers are the greater from being concealed. It is probably correct, as has been lately pointed out, that in deep-laid sewers the pressure inwards of the water of the surrounding soil is so great as frequently to cause an inflow *into* the sewer, and so prevent the exit of the contents; but in other cases, the damage to the sewer may be too great to be neutralised in this way, and in the instance of superficially laid and choked-up pipes, the pressure outwards of the contents must be considerable.* The dangers of sewers are therefore so great that many persons are inclined to think their use an entire mistake, but this is probably going much too far if the securities above noted can be obtained; these securities are, a good supply of water, properly constructed and well ventilated sewers, and means of disposal of the sewage water. If these three conditions can be brought together, sewers for excreta are not hurtful.

### *Amount of Water for Sewers intended for Excreta.*

Engineers are by no means agreed on the necessary amount. In the chapter on WATER, I named 25 gallons per head per diem, on the authority of Mr Brunel, as the amount required to keep common sewers clear, and even with this amount there should be some additional quantity for flushing. But in some cases, a good fall and well-laid sewers may require less, and in other cases, bad gradients or curves or workmanship may require more. It is a question whether rain water should be allowed to pass into sewers; it washes the sewers thoroughly sometimes, but it also carries *dèbris* and gravel from the roads, which may clog; while in other cases, storm waters may burst the sewers, or force back the sewage.†

### *Construction of Sewers.*

Sewers are differently constructed according to the purposes they are to serve, *i.e.*, whether simply to carry off house and trade water, or the solid excreta in addition, or one or both, with the rainfall.

In following out the subject, it will be convenient to trace the sewers from the houses to the outfall.

### *House Pipes and Drains.*

It will be convenient to call the conduits inside the house, which run from sinks and closets, "house pipes," and to give the term "drain pipes" to the conduits which receive the house pipes, and carry the house water into tanks or main sewers. The house pipes may be divided into sink and water-closet or soil pipes; they are made of metal (lead, iron, or zinc, or two of these) or of earthenware. The drain-pipes are usually made of well-burnt, hard, smooth, glazed earthenware.‡ All bricks, porous earthenware, or substances of the kind, should be considered inadmissible for drain pipes. Iron pipes, unless thoroughly cemented inside, are not good.§ The pipes and drains vary in size from 4 to 16 inches diameter,* but the usual size is 5 to 8 inches; they are round or oval in shape.†

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* In Frankfort the sewers were made with good and well-cemented bricks, and yet Pettenkofer found a stream of water in them before the sewer water had been allowed to enter. On the other hand, in Munich, in a sewer of common brick and cement, the water flowed out so fast that a flask of 750 C.C. was filled in fifteen minutes (Roth and Lex. *op. cit.* p. 430). To avoid the entrance of subsoil water, a plan has lately come into use in this country of having an under drain for the subsoil water, and pipe drains of this kind are now made by Messrs Brooke of Huddersfield.

† Storm overflows require to be provided; for a description of them see Bailey Denton, *op. cit.* sections lxii. and lxxxv.

‡ Mr Baldwin Latham cautions us to see that the *socket* of the drain-pipe is made with, and is a component part of the pipe, and not merely joined on.

§ Perhaps Barff's process may become applicable. Iron pipes with lead joints are found good among trees, the roots of which often penetrate the joints of earthenware pipes when not carefully laid. Concrete is also well spoken of. Coating the pipes and joints with coal-tar prevents (according to Mr Mechi) the penetration of weeds and roots.

*Connection of House Pipes with the Drains.*—It is customary to commence the drains at the basement of the house, and the sink and closet pipes pass down inside the house and join on, a water-trap being placed at the junction.‡ As the aspiratory power of the warm house is then constantly tending to draw air through the water-trap, and as the trap is liable to get out of order, it is most desirable to alter this plan. The drains should end outside the house, and as far as possible every house pipe should pass outside and not inside or between walls to meet the drain. The object of this is that any imperfection in the pipe should not allow the pipe air to pass into the houses. At the junction of the house pipe and drain, there should not only be a good water-trap, but one of the plans proposed by engineers should be adopted, by means of which there is a complete ventilation and connection with the outside air at the point of junction. The rule, in fact, should be, that the union of any house pipe whatever with the outside drain should be broken both by water and by ventilation (see page 371). In addition, it should be a strict rule, that no drain pipe of any kind should pass under a house; if there must be a pipe passing from front to back, or the reverse, it is much better to take it above the basement floor than underneath, and to have it exposed throughout its course. It is hardly possible to insist too much on the importance of this rule of disconnection between house pipes and outside drains. Late events have shown what a risk the richer classes in this country now run, who not only bring the sewers into the houses, but multiply water-closets, and often put them close to bedrooms. The simple plan of disconnection, if properly done, would insure them against the otherwise certain danger of sewer air entering the house. Houses which have for years

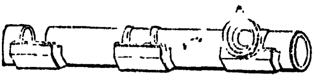

Fig. 82.—Jenning's Access-pipe.

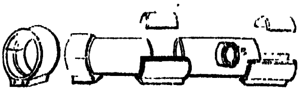

Fig. 83.—Stiff's Access-pipe and Junction.

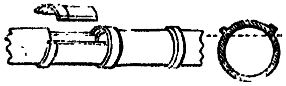

Fig. 84.—Doulton and Watt's Access-pipe.

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kind. This distinction, however, has not been made in the Public Health Act of 1875, and I have therefore made no alteration in the text. (See Bailey Denton's Sanitary Engineering, p. 16.)

† I may refer to a useful little work by Mr William Eassie, called Healthy Houses (2d edition), for much information on this and kindred subjects. Some of the drawings given here have been copied from Mr Eassie's work, by his permission; reference may also be made to Sanitary Arrangements for Dwellings, by the same author.

‡ Builders are always anxious to conceal tubes, and thus carry them inside the walls, or in the case of hollow walls, between the two. The consequence is that any escape of air must be into the house. I have known a case in which the leakage of a closet pipe carried down in a hollow wall constantly contaminated the air of the house. It would be infinitely better to run the pipes at once through the wall to the outside. Few persons have any idea of the carelessness of plumbers' work—of the bad junctions, and of the rapidity with which pipes get out of order, and decay. When a leaden pipe carrying water is led into a water-closet discharge pipe, it is frequently simply puttied in, and very soon the dried putty breaks away, and there is a complete leakage of gas into the house. Even if well-joined, the lead pipe will, it is said, contract and expand, and thus openings are at last formed. Dr Fergus of Glasgow has directed particular attention to this, in the case of lead closet pipes, which become easily perforated, and which have only a limited duration of wear.

been a nuisance from persistent smells have been purified and become healthy by this means.

*Cleaning of Pipes and Drains.*—Pipes are cleaned by flexible bamboo or jointed rods with screws and rollers to loosen sediment. But for perfect safety it is desirable to have drain pipes which can be opened at intervals by means of lids or caps. Several kinds of pipes of this kind ("access-pipes") are now made, and Mr Eassie states that many architects always include them in their specifications. Drain pipes should also be cleared out by regular flushing, carried out not less often than once a month.

*Laying of Drains.*—They should be laid very carefully on concrete in all loose soils, and on well-worked puddled clay in clay soils. Sometimes, in very loose soils, even piling for the depth of a foot must be used besides the concrete. When pipes are not laid on a good foundation, leakage is sure to occur sooner or later, and the final expense is far more than the first outlay would have been. The greatest care must be taken in laying and joining the pipes. In a wet soil, a good plan is to have a firm basis, which is itself perforated to carry off subsoil water, and to put the drain over this as in the plan of Messrs Brooke and Son of Huddersfield (see fig. 96).

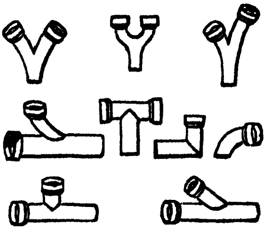

Fig. 85.—Junctions.

The "junction" of pipes is accomplished by special pipes, known by the names of single and double squares, curved or oblique junctions, according to the angle at which one pipe runs into the other. The square junctions are undesirable, as blockage will always occur, and the oblique junctions should be insisted upon. When one pipe opens into another, a taper pipe is often used; the calibre being contracted before it enters the receiving pipe.

*Fall of Drain Pipes.*—1 in 48 is frequently given, or ¾ inch in every yard; a fall of 1 in 65 in drains of 6 inches diameter, and 1 in 87 in drains of 8 inches diameter, will give a velocity of 220 feet per minute. Mr Eassie says "the best practice is to allow a fall of 2¾ or 3 inches to every 10 feet," that is about 1 in 40.

*House-Traps.*—As the traps are usually the only safeguard against the warm house drawing sewer air into it, the utmost attention is necessary to insure their efficiency. There is almost an infinite diversity, but they can be conveniently divided into the syphon, the midfeather, the flap-trap, and the ball-trap.

The syphon is a deeply-curved tube, the whole of the curve being always full of water. It is a useful trap, and efficient if the curve is deep enough, so that there is a certain depth of water (not less than ¾ inch) standing above the highest level of the water in the curve, and if the water is never sucked out of it, and if the pipe is not too small, so that the water is carried away when it runs full, by the syphon action of the pipe beyond.

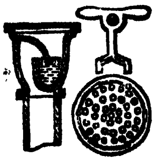

Fig. 86.—Antill Trap and Lock Grate.

The midfeather is in principle a syphon; it is merely a round or square box, with the entry at one side at the top, and the discharge-pipe at a corresponding height on the opposite side, and between them a partition reaching below the lower margin of both pipes. Water, of course, stands in the box or receptacle to the height of the discharge, and therefore the partition is always to some extent under water. The extent should not be less than three-fourths of an inch. Heavy substances may subside and collect in the box, from which they can be removed from time to time. The common ball-trap, with its modifications, is a variety of the midfeather-trap. I figure a good kind of common sink trap.

The flap is used only for some drains, and is merely a hinged valve which allows water to pass in one direction, but which is so hung as to close afterwards by its own weight. It is intended to prevent the reflux of water into the secondary drains, and is supposed to prevent the passage of sewer gas. But it is probably a very imperfect block.

The ball-trap is used in some special cases only; a ball is lifted up as the water rises, until it impinges on and closes an orifice.

However various may be the form and details of the water-trap, they can be referred to one or other of these patterns.

*Efficiency of Traps.*—Supposing, of course, they are properly laid, a trap is efficient, if water stands in it to the height of ¾ inch above openings, if water passes through it sufficiently often, and with force enough to clear out the receptacle and renew the water in it. But traps are often ineffective—1*st*, From bad laying, which is a very common fault. 2*d*, From the water getting thoroughly impregnated with sewer effluvia, so that there is escape of effluvia from the water on the house side. 3*d*, From the water passing too seldom along the pipe, so that the trap is either dry or clogged. 4*th*, From the pipe being too small (2 or 3 inches only) and "running full," which will sometimes suck the water out of the trap; it usually occurs in this way, as frequently seen in sink traps: the pipe beyond the trap has perhaps a very great and sudden fall, and when it is full of water it acts like a syphon and sucks all the water out of the trap; to avoid this, the pipe should be large enough to prevent its running full, or the trap should be of larger calibre than the rest of the pipe. 5*th*, Traps may perhaps be inefficient from the pressure of the sewer air, combined with the aspirating force of the house displacing the water and allowing the air uninterrupted communication between the sewer and the house. The extent of the last danger cannot be precisely stated. From a long series of observations on the pressure of the air in the London sewers, Dr Burdon-Sanderson ascertained that, in the main sewers at any rate, the pressure of the sewer air, though greater than that of the atmosphere, could never displace the water in a good trap. In a long house-drain which got clogged, and in which much development of gaseous effluvia occurred, there might possibly be for a time a much greater pressure, but whether it would be enough to force the water back, with or without the house suction, has not been yet experimentally determined. But the reasons already given show that we ought not to place dependence solely on traps,* though they are useful adjuncts. In arranging the house pipes, it is desirable not to carry the sink and waste-water pipes into the closet soil-pipes, but if it can be done, to let them empty in the open air over a grating. In the case of soil or water-closet pipes, or of the pipe formed by the junction of soil and waste-water pipes (if such junction cannot be avoided), there must be also a complete air-disconnection between the pipe and drain by means of one of the contrivances now used

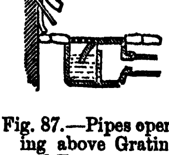

Fig. 87.—Pipes opening above Grating and Trap.

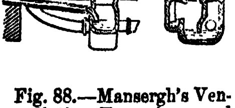

Fig. 88.—Mansergh's Ventilating Trap, improved by Jennings.

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* "Honestly speaking, traps are dangerous articles to deal with; they should be treated merely as auxiliaries to a good drainage system." (Eassie.)

by engineers. At the point where this disconnection is made, there ought to be some easy means of getting at it for inspection.

There are various plans of disconnecting the house pipe and outside drain. The simplest plan is to trap just outside the house; to open the drain on the side of the trap most distant from the house, and to carry up a 4-inch pipe to as great a height as can be managed.

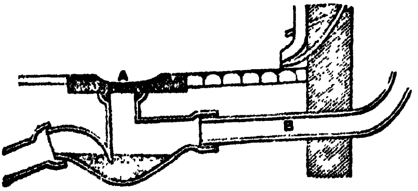

Fig. 89.—Molesworth's Trap. B, House pipe. A, Grating to receive overflow of rain-pipe, and to allow efflux of gas if the water-trap is forced. C, Drain.

In Mansergh's "ventilating trap" there is a small trap connected with the house pipe, and a larger one connected with the drain pipe, opposite to which is a ventilating pipe of 4 inches diameter, running up to the top of the house. Between the house pipe and the drain pipe is the water of the trap, surmounted by a grating to the open air. Another plan is, to have a syphon or midfeather-trap, with a grating over the water in the trap which is nearest the house. The rain-water pipes, and the pipes carrying merely waste washing or bath-water, can open over this grating. If the sewer air is forced back, it will rise through the grating in all probability, or if drawn into the house, will be much diluted. One advantage of this plan is, if the trap gets dry or clogged, and foul air passes through the grating, it is soon detected, and the trap is examined. Professor Reynolds[*] has suggested an arrangement which seems very good and simple.

A man-hole is sunk about two feet square, to the outside drain, and an open cemented trough is formed of the same width as the drain; the house pipe on one side and the drain on the other are connected with the trough, but are depressed so that the water stands in the trough half-an-inch higher on the sewer side, and one inch above the mouth of the pipe on the house side. There is, in fact, a double midfeather water-trap, so to speak, and an opening over the water between the two, which will allow gas to escape if it forces its way from the sewer.

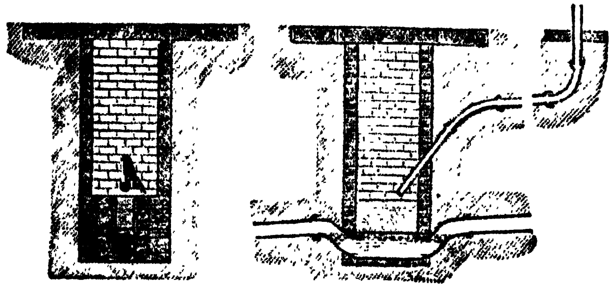

Fig 90—Reynolds's Man-hole and Trough, and Rain-spout opening over Trough.

Professor Reynolds considers that if this arrangement is adopted no other traps will be necessary, and all the house pipes may be left untrapped except the closet pipe.

A rain-water pipe may open above the open part of the trough to clear away any scum which may collect in the trough. The plan may be carried out more simply by inserting a pipe in the centre of a syphon, and carrying this pipe to the surface, or higher if considered desirable. There are various similar arrangements. The "Somerset Patent Trap," designed by Mr Honeyman, and much used at Glasgow, is a midfeather trap with an air-shaft on each side the partition; on one side the shaft ventilates the pipe leading to the sewer; on the other, allows fresh air to pass into the house pipe. This second shaft also allows the trap to be cleaned.*

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[*] Sewer Gas, by Osborne Reynolds, M.A., Professor of Engineering at Owen's College, Manchester. 2d edition. 1872.

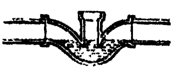

Fig. 91.—Syphon ventilated in the Middle.

Rain-water pipes are sometimes used to ventilate drains, but independent of their small size, which often leads to blockage, they are often full of rain, and cannot act at the time when ventilation is most required.

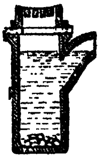

Fig. 92.—Simple Gulley Trap.

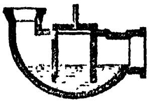

Fig. 93.—Cottam's Effluvium Trap.

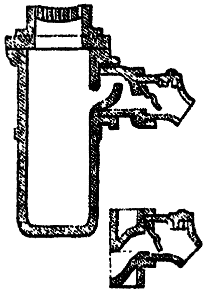

Fig. 94.- Doulton's Valve and Flap Road Gully.

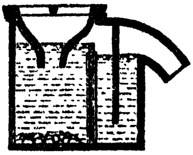

Fig. [illegible] -Halbard's Gulley Trap, with 3 Water-valves

In yards, gully traps of different kinds are used, the action of which will be at once understood from the drawings.

### *nation of House Pipes and Traps.*

Pipes and traps are generally so covered in that they cannot be inspected; but this is a bad arrangement. If possible, all cover and skirting boards concealing them should be removed, and the pipe and trap underground laid bare, and every joint and bend looked to. But supposing this cannot be done, and that we must examine as well as we can in the dark, so to speak, the following is the best course. Let water run down the pipe, and see if there is any smell; if so, the pipe is full of foul air and wants ventilation, or the trap is bad. If a lighted candle, or a bit of smouldering brown paper, is held over the entrance of the pipe or the grating over a trap, a reflux of air may be found with or without water being poured down. It should be noticed, also, whether the water runs away at once, or if there is any check. This is all that can be done inside the house; but though the pipe cannot be disturbed inside, it may be possible to open the earth outside, and to get down to and open a drain; in that case, pour water mixed with lime down the house pipe; if the whitened water is long in appearance, and then runs in a dribble merely, the drains want flushing; if it is much coloured and mixed with dirt, it shows the pipes and trap are foul, or there is a sinking or depression in some part of the drain where the water is lodging. The pipe should then be flushed by pouring down a pailful of lime and water till the limewater flows off nearly clear.

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* The forms of traps lately introduced are very numerous, some apparently very good, such as Potts' Edinburgh Trap and Banner's Trap; others would probably be fairly efficient, whilst some would be really useless. Drawings of many will be found in Mr Eassie's and Mr Bailey Denton's works

Yard-traps are often very foul, and if the trap-water be stirred, gas bubbles out, which is a sign of great foulness, or that the traps are seldom used.

### *Main Sewers.*

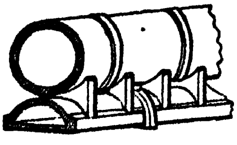

Fig. 96.—Brooks's combined Drain and Subsoil Pipe.

The outside house drain ends in a channel which is common to several drains, and which is of larger size. These larger sewers are made either of round glazed earthenware pipes from 15 to 24 inches diameter, or of well-burnt impervious brick moulded in proper curved shape and set in Portland cement, or stoneware bricks are partly used. The shape now almost universally given, except in the largest outfall part, is that of an egg with the small end downwards. Engineers take the greatest care with these brick sewers; they are most solidly put together in all parts, and are bedded on a firm unyielding bed. Much discussion has taken place as to their size, and the general opinion of engineers appears to be, that a street or main drain should be large enough to allow a man to creep through, but that all other sewers should be smaller, and with such a fall as to be self-cleansing.

Sewers should be laid in as straight lines as possible, with a regular fall; tributary sewers should not enter at right angles, but obliquely; and if the sewer curves, the radius of the curve should not be less than 10 times the cross sectional diameter of the sewer. Sometimes there is an arrangement for subsoil drainage under a pipe drain, as in the plan proposed by Mr Brooks.

The fall for street drains is usually from 1 in 244 to 1 in 784, according to the size of the drain. The flow through a sewer should in no case be less than 2 feet per second, and 3 is better. As in the house drain, the fall should be equable without sudden changes of level.*

### *Access to Sewers.*

It is of importance that to all sewers capable of being entered by a man, there should be an easy mode of access. Man-holes opening above, or, what is better, at the side, should be provided at such frequent intervals, that the sewers can be entered easily and inspected at all points. The man-holes are sometimes provided with an iron shutter to prevent the sewer air passing into the street, or by the side of the man-hole there may be a ventilating chamber with trays of charcoal.†

### *Calculation of Discharge from Sewers.*‡

Several formulæ have been given, of which the following is the most simple:—

$$V = 55 \times (\sqrt{D \times 2F}) \times A.$$

V = velocity in cubic feet per minute.
D = hydraulic mean depth.
F = fall in feet per mile.
A = section area of current of fluid.

To use this formula, the hydraulic mean depth when the sewage is flowing, and the amount of fall in feet per mile, must be first ascertained. The hydraulic mean depth is ¼th the diameter if the pipe is running full; if the pipe is not full, it is the section area of current of fluid divided by the wetted perimeter. The wetted perimeter is that part of the circle of the pipe wetted by the fluid. The fall in feet per mile is easily obtained, as the fall in 50 or 100 or 200 feet can be measured, and the fall per mile calculated (5280 feet = 1 mile). Having got these numbers, multiply the hydraulic mean depth by twice the fall in feet per mile, and take out the square root. Multiply this by 55, and the result by the section area. The number obtained gives the amount in cubic feet per minute.

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* In some cases a fall is almost impossible to obtain, as, for instance, at Southport, in Lancashire, where the ground is nearly a dead level. The fall there is about 1 in 5000, and never exceeds 1 in 3000. In such a case the drain would have to be cleaned either by locks or valves (flushing-gates) to retain a portion of the contents for a time, and then set them free suddenly in order to flush the next section.

† Mr Baldwin Latham joins the sewers in man-holes, so that if one is blocked another may be used; the outlet being at the lower level.

‡ The following table, taken from Mr Wicksteed, will be found useful:—

### *Movement of Air in the Sewers and Ventilation.**

It seems certain that no brick sewer can be made air-tight; for on account of the numerous openings into houses, or from leakage through brickwork, or exit through gratings, man-holes, and ventilating shafts, the air of the tubes is in constant connection with the external air. There is generally, it is believed, a current of air with the stream of water if it be rapid. The tension of air in main sewers is seldom very different from that of the atmosphere, or if there be much difference equilibrium is quickly restored. In twenty-three observations on the air of a Liverpool sewer, it was found by Dr Burdon-Sanderson and myself,† that in fifteen cases the tension was less in the sewer than in the atmosphere outside (*i.e.*, the outside air had a tendency to pass in), and in eight cases the reverse; but on the average of the whole, there was a slight indraught into the sewer. In the London sewers, on the other hand, Sanderson noticed an excess of pressure in the sewers.

If at any time there is a very rapid flow of water into a sewer, as in heavy rains, the air in the sewer must be displaced with great force, and possibly

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*Sewers.*

| Diameter. | Velocity in feet per minute. | Gradient required. |
|---|---|---|
| 4 inches | 240 | 1 in 36 |
| 6 ,, | 220 | 1 ,, 65 |
| 8 ,, | 220 | 1 ,, 87 |
| 9 ,, | 220 | 1 ,, 98 |
| 10 ,, | 210 | 1 ,, 119 |
| 15 ,, | 180 | 1 ,, 244 |
| 18 ,, | 180 | 1 ,, 294 |
| 21 ,, | 180 | 1 ,, 343 |
| 24 ,, | 180 | 1 ,, 392 |
| 30 ,, | 180 | 1 ,, 490 |
| 36 ,, | 180 | 1 ,, 588 |
| 48 ,, | 180 | 1 ,, 784 |

Mr Latham (Lectures on Sanitary Engineering, delivered to the Royal Engineers at Chatham) gives a table, of which the following is an extract:—

| Diameter in inches. | Rate of inclination for velocity per second. | | | | |
|---|---|---|---|---|---|
| | 2 feet. | 3 feet. | 4 feet. | 5 feet. | 6 feet. |
| 4 | 1:194 | 1:92 | 1:53 | 1:34 | 1:24 |
| 6 | 292 | 137 | 80 | 51 | 36 |
| 8 | 389 | 183 | 106 | 69 | 48 |
| 9 | 437 | 206 | 119 | 77 | 54 |
| 10 | 486 | 229 | 133 | 86 | 60 |
| 12 | 583 | 275 | 159 | 103 | 72 |

In this table the velocity in feet multiplied by the inclination equals the length of the sewer to which the calculation applies. For example, if the velocity is 6 feet per second in a pipe whose diameter is 4 inches, then 6 × 24 = 144 feet is the length of the sewer.

* For composition of sewage air, see p. 108.

† Report on the Sanitary Condition of Liverpool, 1870, p. 27.

may force weak traps; but the pressure of air in the sewers is not appreciably affected by the rise of the tide in the case of seaboard towns.* The tide rises slowly, and the air is displaced so equably and gradually through the numerous apertures, that no movement can be detected. It is not possible, therefore, that it can force water-traps in good order.

On the contrary, the blowing off of steam, or the discharge of air from an air-pump (as in *some* trade operations), greatly heightens the pressure, and might drive air into houses. So also the wind blowing on the mouth of an open sewer must force the air back with great force.

It is, therefore, important to protect the outfall mouth of the sewer against wind by means of a flap, and to prohibit steam or air being forced into sewers.

To how great an extent it is the openings into houses which thus reduce the tension of the air in main sewers is difficult to say, but there can be little doubt that a large effect is produced by houses which thus act as ventilating shafts.

When a sewer ends in a *cul de sac* at a high-level sewer, gas will rise and press with some force; at least in one or two cases, the opening of such a *cul de sac* has been followed by so strong a rush of air as to show that there had been considerable tension. It is also highly probable, from the way in which houses standing at the more elevated parts of sewers, and communicating with them, are annoyed by the constant entrance of sewer air, while houses lower down escape, that some of the gases may rise to the higher levels.

That no sewer is air-tight is certain, but the openings through which the air escapes are often those we should least desire. It is therefore absolutely necessary to provide means of exit of foul and entrance of fresh air, and not to rely on accidental openings. The air of the sewer should be placed in the most constant connection with the external air, by making openings at every point where they can be put with safety. In London there are numerous gratings which open directly into the streets, and this plan, simple and apparently rude as it is, can be adopted with advantage whenever the streets are not too narrow. But in narrow streets the sewer gratings often become so offensive that the inhabitants stop them up. In such cases, the outpouring sewer air must be deodorised with charcoal, or there must be ventilating shafts of as large a diameter as can be afforded, and running up sufficiently high to safely discharge the sewer air.† In some of these cases it may be possible to connect the sewers with factory chimneys.‡ The sewer should never be connected with the chimneys of dwelling-houses.

In making openings in sewers it seems useless to follow any regular plan. The movement of the sewer air is too irregular to allow us to suppose it can ever be got to move in a single direction, though probably the most usual course of the air current is with the stream of water, if this be rapid. The openings should be placed wherever it can conveniently be done without creating a nuisance. Some of these openings will be inlets, others outlets, but in any case dilution of the sewage effluvia is sure to be obtained. Mr Rawlinson considers that every main sewer should have one ventilator every 100 yards, or 18 to a mile, and this should be a large effective opening.§

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* *Vide* same Report, p. 21, for the case of Liverpool. Dr Corfield's observation at Scarborough was confirmatory.

† In Liverpool there are small shafts with Archimedean screws at the top. From the observations of Sanderson and myself, it appears that these screws do act, but not to such an extent as to warrant the expense.

‡ It seems inadvisable to erect chimneys and use fires with an idea of ventilating the sewers on a general plan, the air would simply be drawn with great force through the nearest openings. But local ventilation by a factory chimney, when gratings cannot be used, is a different thing.

§ Others have recommended one in 50 yards.

But there may be cases when special appliances must be used. For example, in what are called "sewers of deposit," as when the outflow of the sewer water is checked for several hours daily by the tide or other causes, it may be necessary to provide special shafts, and the indication for this will be the evidence of constant escape of sewer-air at particular points.

*Charcoal Trays.*—The use of charcoal traps (as recommended by Stenhouse) in such shafts, or at the side of gratings, is becoming very common. The charcoal should be in pieces about the size of a small bean, and should be in two or three strata of from 2 to 3 inches each in thickness. It should be protected from wet, and will then act for years. If too thickly laid, or if pressed together, the charcoal may impede the movement of the air.

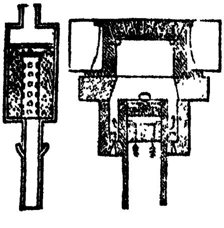

Fig. 97.—Charcoal Trays. Sewer Outlet Pipes.

In the city of London, the boxes used by Mr Heywood are of iron, 18 inches deep and 14 inches wide, and containing six trays, each containing charcoal pieces as large as filberts, 2 inches deep. The sewer gas must pass through the charcoal and not over it; the air, after passing through the charcoal, is inodorous; the charcoal absorbs gases and organic matter, which it oxidises into nitric acid; it also absorbs a good deal of water, but this does not impair its power.*

Mr Baldwin Latham has invented a very excellent plan. The charcoal is in a spiral tray, and special arrangements are made to prevent the charcoal getting wet, and receiving dirt from the streets.

### *Inspection of Sewers.*

The inspection of sewers is in many towns a matter of great difficulty, on account of the means of access being insufficient, and also because the length of the sewers is so great. Still inspection is a necessity, especially in the old flat sewers, and should be systematically carried out, and a record kept of the depth of water, the amount of deposit, and of sewer-slime on the side or roof.

*Choking of and Deposits in Sewers.*—Causes—Original bad construction; too little fall; sharp curves; sinking of floor; want of water; check of flow by tides, so that the heavy parts subside.

Well made sewers with a good supply of water are sometimes self-cleansing and quite free from deposit, but this is, unfortunately, not always the case.

Even in so-called self-cleansing sewers, it has been noticed by Mr Rawlinson that the changing level of the water in the sewers leaves a deposit on the sides, which, being alternately wet and dry, soon putrifies. In foul sewers a quantity of slimy matter collects on the crown of the sewers; it is sometimes 2 to 4 inches in thickness, and is highly offensive. When obtained from a Liverpool sewer by Dr Burdon-Sanderson and myself, we found it alkaline from ammonia and containing nitrates.† On misroscopic examination, this Liverpool sewer-slime contained an immense amount of fungoid growth and

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* Miller, Chem. News, March 1868. An able writer in the Lancet, May 1872, states that for every square inch of surface outlet there should be 50 square inches of charcoal trays. Recent experience has rather discredited the use of charcoal trays; the charcoal requires to be frequently changed and often gets clogged with dust, so as to act as an obstruction. See Bailey Denton's Sanitary Engineering, pp. 213, 214.

† Report on the Sanitary State of Liverpool by Drs Parkes and Burdon-Sanderson, 1871. The amount of free ammonia was ·025 parts per cent.; the albuminoid ammonia was ·00462, and the nitric acid ·2035 parts per cent. Photographs are given of the microscopic appearances of the slime in this report.

Bacteria, as well as some confervæ. There were also acari and remains of other animals and ova.

When deposits occur, they are either removed by the sewer-men, or they are carried away by flushing of water.

*Flushing of Sewers.*—This is sometimes done by simply carrying a hose from the nearest hydrant into the sewer, or reservoirs are provided at certain points which are suddenly emptied. The sewer water itself is used for flushing, being dammed up at one point by a flushing-gate, and when a sufficient quantity has collected the gate is opened.* Some towns (as Leeds) are adopting self-acting tumblers for water-closets, *i.e.*, water-troughs working on an eccentric axis and receiving water at a regulated rate until the trough is filled to a certain point; it then turns over, so that the contents pour suddenly into the closet. It then rights itself, and the water fills it slowly to the proper point again. A plan of this kind is equally applicable to sewers.

Almost all engineers attach great importance to regular flushing, and the advantage of allowing the rain to enter the sewers is the scouring effect of a heavy rainfall which is thus obtained.

## DISPOSAL OF THE SEWER WATER.

The great engineering skill now available in all European countries can ensure in the case of any new works that the construction of sewers shall be perfect. If an engineer can obtain good materials, good workmen, and a proper supply of water, there is no doubt that sewers can be so solidly constructed and so well ventilated that the danger of deposits in the sewers, or of sewer air entering and carrying disease into houses, is removed.

But the difficulty of the plan of removing excreta by water really commences at the outfall. How is the sewer water to be disposed of?

This difficulty is felt in the case of the foul water flowing from houses and factories without admixture of excreta almost as much as in sewer water with excreta. The exclusion of excreta from sewers, as far as it can be done, would not solve the problem—would, indeed, hardly lessen its difficulty. In seaboard towns the water may flow into the sea, but in inland towns it cannot be discharged into rivers, being now prohibited by law. Independent of the contamination of the drinking water, the sewer water often kills fish, creates a nuisance which is actionable, and in some cases silts up the bed of the stream. It requires in some way to be purified before discharge. At the present moment the disposal of the sewer water is the sanitary problem of the day, and it is impossible to be certain which of the many plans may be finally adopted. It will be convenient to briefly describe these plans.

### 1. *Storage in Tank, with Overflow.*

The sewer water runs into a cemented tank with an overflow-pipe, which sometimes leads into a second tank similarly arranged, the solids subside, and are removed from time to time; the liquid is allowed to run away. Instead of letting the liquid run into a ditch or stream, it has been suggested to take it in drain pipes, ½ to 1 foot under ground, and so let it escape in this way into the subsoil, where it will be readily absorbed by the roots of grasses. In a light soil this could no doubt be readily done; and, if the drain pipes are well laid, a considerable extent of grass land could be supplied by this subterranean irrigation. The tank plan is, however, only adapted for a small scale, such as a single house or small village, and there should be ventilation between the tank and the house in all cases.

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* Baldwin Latham points out that there is a point of flow in all sewers when they discharge more than when running full. A good flushing power may be obtained at considerably less than the full discharge. Tables are given in his Sanitary Engineering.

### 2. *Discharge at once into Running Water.*

All new works of this description are now prohibited, and the plan will probably ultimately cease in this country.[*]

### 3. *Discharge into the Sea.*

The outlet pipe must be carried to low water, and, if possible, should be always under water. A tide flap opening outwards is usually provided. If not under water constantly, special care must be taken to prevent the wind blowing up the sewers. The tide will fill the outfall sewers (which are generally made large) to the level of high water, and to that extent will check the discharge, and in the sewers filled with the mixed sea water and sewage there will be deposit. To remove this special attention is necessary.

If the sewage cannot be got well out to sea, and if it issues in narrow channels, it may cause a nuisance, and may require to be purified before discharge. In the Rivers Pollutions Act (1876) power is given to prohibit discharge into the sea or tidal waters under certain circumstances.[†]

### 4. *Precipitation.*

Another plan is not to pour the whole sewage into rivers, but to precipitate the solid part, or the greater portion of it, and then to allow the liquid to pass into the stream or over the land.

This is sometimes done by simple subsidence, the sewage being received into settling reservoirs or trenches, with strainers to arrest the flow to some extent. When the solid matter has collected to a certain amount, the sewage is turned into another reservoir, and the thick part, being mixed with coal refuse or street sweepings, is sold as manure.

The thin water which runs off must be almost as dangerous as the sewage itself when poured into streams, and consequently the prohibition to discharge sewer water extends to it also.

In order to produce greater purification, the sewage in the subsiding tanks

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[*] When sewer water passes into a river it undergoes considerable purification by subsidence, by the influence of water plants, and in a lesser degree by oxidation. Although some oxidation of nitrogenous organic matters into nitrous and nitric acids and ammonia must take place, it appears from Franklin's experiments,[*] that in the river Irwell, which receives the sewage of Manchester, after a run of 11 miles, and falling over six weirs, there is no formation of nitrites and nitrates, and there is even an increase in the organic nitrogen (?), though the suspended matters are less (from 2·8 to 1·44 parts per 10,000) than at first. Average London sewage diluted with 9 parts of water and syphoned from one vessel into another so as to represent a flow of 96 and 192 miles, gave a percentage reduction in the organic nitrogen of 28·4 and 33.3 respectively. The oxidation of sewage appears, then, from these experiments, to take place slowly. Dr Letheby considers, however, that oxidation takes place more rapidly, and that if sewage is mixed with 20 times its bulk of water, and flows for 9 miles, it will be perfectly oxidised.[†] Of course, it is clear that ova, and solid parts of the body, like epithelium, might be totally unchanged for long periods,[‡] and we may conclude that oxidation of sewage in running water cannot be depended on for perfect safety.

[†] The word "stream" (into which sewage is not to be passed) is defined by section 20 of the Act, thus :—"Stream includes the sea to such extent and tidal waters to such point, as may, after local inquiry and on sanitary grounds, be determined by the Local Government Board, by order published in the London Gazette. Save as aforesaid, it includes rivers, streams, canals, lakes, watercourses, other than watercourses, at the passing of this Act, mainly used as sewers, and emptying directly into the sea or tidal waters, which have not been determined to be streams within the meaning of this Act by such order as aforesaid."

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[*] Reports of the Commissioners appointed to inquire into the Pollution of Rivers, 1870, vols. i. ii. and iii.

[†] Report of East London Water Bill Committee (1867), p. 480, question 732–4.

[‡] As formerly mentioned, I have found unchanged epithelium in unfiltered Thames water after a transit in a barrel of 80 miles, and after keeping for five months. It was very transparent and worn, but quite recognisable.

is now usually mixed with some chemical agency which may precipitate the suspended matters.

Numerous substances have been employed as precipitants.*

*Lime Salts.*—Quicklime (proportion 8 to 12 grains per gallon), or 1 ℔ of lime for 600 gallons of sewage (nearly); chloride of lime which is added to quicklime in the proportion of about $\frac{1}{40}$th part of chloride to 1 of lime; calcic phosphate dissolved in sulphuric acid, or a mixture of mono- and di-calcic phosphate with a little lime (Whitthread's patent),† are said to be good precipitants. Chloride of calcium has been also recommended.

*Albuminous Substances.*—Aluminous earth mixed with sulphuric acid (Bird's process); impure sulphate of aluminium (Anderson's and Lenk's processes); refuse of alum works, either alone or mixed with lime or charcoal; clay mixed with lime (Scott's cement process); natural phosphate of aluminium dissolved by sulphuric acid and mixed with lime. In all these cases the amount of the substance added is from 50 to 80 grains per gallon of sewer water.

*Magnesian Salts* mixed with lime in the form of superphosphates (Blyth); impure chloride of magnesium.

*Carbon* in the shape of vegetable charcoal; peat; seaweed charcoal; carbonised tan; lignite; Boghead coke. On a small scale charcoal answers fairly, and the residue is a valuable manure.

*Iron* in the shape of sulphate; perchloride (Ellerman's and Dale's liquid); the sulphate is sometimes mixed with lime and coal dust.

*Manganese.*—Condy's fluid.

*Zinc* sulphate and chloride.

The deposit obtained from any of these processes is collected and dried. It is usually dried on a hot floor, a stream of hot air being allowed also to pass over it. There is some little difficulty in drying it, but this is now being overcome. Of these various precipitants the best appear to be the aluminous preparations; the crude sulphate of alumina prepared by Dr Anderson of Coventry; the solution patented by Mr Lenk; the A, B, C process of Mr Sillar, which consists of alum, blood, charcoal, and clay; ‡ and Mr Forbes' sulphuric acid solution of natural phosphate of alumina. All produce rapid subsidence of the suspended matters, and clarify the liquid to a very great extent. The sulphuric acid also tends to prevent decomposition of the deposit. In using these substances the sewage water is received into a tank or well, and there, or on its way thither, receives the precipitating agent, which is generally mixed by means of a screw or turbine. After thorough mixing, the precipitate is allowed to subside, and the superabundant water is run off. The deposit is then dug out and dried. After drying the deposit appears to possess some agricultural value,§ and to be saleable at a price which, in some cases, leaves a small profit. The profit is never large, and in some instances there has been even a loss. The clear water from all these processes contains ammonia and oxidisable organic matters, as well as phosphoric acid (in most cases) and potash, and it would thus appear that a considerable part of the substances which give fertilising power to sewage remain in the effluent water.

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* An interesting account of the precipitating processes is given in a book called The Sewage Question, the author of which has had the advantage of Dr Letheby's notes and analyses. A list of no less than 57 processes or proposals is given at page 38, from which it appears that the first precipitant was proposed by Deboissieu so long ago as 1762, and was a mixture of acetate of lead and proto-sulphate of iron.

† This patent was found to give good results in removing suspended matters and organic nitrogen, and the Committee of the British Association considered the process deserved "further investigation." It appears, however, to have come at present to a standstill.

‡ The proportions are stated to be, 6 grains of alum, ¼ grain of blood, 20 grains of clay, and 6 grains of charcoal, to 10,000 grains of sewer water. Sometimes a little lime is added.

§ This never exceeds one third of the theoretical or chemical value. Thus the product by Anderson's process at Coventry is estimated *theoretically* at 16s. 9½d. per ton; the *practical* value is only 5s. 6d. to 8s. 4d. See Dr Voelcker's Reports, in the Report of a Committee on Town Sewage, (1876), p. lx. *et seq.*

The caustic lime process, when properly applied, appears also to be a powerful precipitant, but the deposit has no agricultural value.

The metallic precipitants of various kinds (iron, zinc, manganese) are more expensive and less useful. Blyth's magnesian process was unfavourably reported on by Mr Way.

When the sewer water is cleared by any of these plans, is it fit to be discharged into streams ? In the opinion of some authorities, if the precipitate is a good one it may be so, and it appears certain that in many cases it is chemically a tolerably pure water, and it will no longer silt up the bed or cause a nuisance. But it still contains in all cases some organic matter, as well as ammonia, potash, and phosphoric acid.[*] It has, therefore, fertilising powers certainly, and possibly it has also injurious powers. No proof of this has been given, but also no disproof at present, and when we consider how small the agencies of the specific diseases probably are, and how likely it is that they remain suspended, we do not seem to be in a position to expect that the water, after the subsidence of the deposit, will be safe to drink. We must adopt, I believe here, the plan which is the safest for the community ; and the effluent water should therefore be used for irrigation, or be filtered before discharge. The clear fluid is well adapted for market gardens ; the plants grown as vegetables for the table are sometimes injured by irrigation with unpurified sewer water, but they thrive with the purified effluent water.

In arranging any processes for precipitation everything must be as simple as possible ; there is no margin for expenditure on complicated arrangements.

### *Sewage Cement.*

Instead of using the dried deposit as manure, General Scott has proposed to make cement, and for this purpose adds lime and clay to the sewer water. The deposit contains so much combustible matter that it requires less coal to burn it than would otherwise be the case, and the saving thus effected enables (it is supposed) cement to be sold at a remunerative rate. If this should turn out to be the case, the sewage cement process has the advantage of destroying by fire everything which might be injurious in the deposit, while the effluent water, which contains rather more than two-thirds of the chlorine and three-fourths of the dissolved nitrogen, has some value as an irrigator. At present the pecuniary results of the process cannot be properly determined. General Scott also proposes to use the burnt material as manure to *lime* the land in some cases.

### 5. *Filtration through Earth, Charcoal, &c.*

By filtration through earth is meant the bringing of sewer water upon a comparatively small area of porous soil, which is broken up and comminuted above, and is deeply underdrained, so that the sewer water may pass through the soil and issue by the drains. Mr Dyke, in explaining the system employed at Merthyr-Tydvil[†] by Mr Bailey Denton, lays down the following conditions :—There should be—1*st*, a porous soil ; 2*d*, an effluent drain, not less than 6 feet from the surface ; 3*d*, proper fall of land to allow the sewage to spread over the whole land ; and 4*th*, division of filtering area into four parts, each part to receive sewage for six hours, and to have an interval of eighteen hours. He considers that an acre of land would take 100,000 gallons per day, though this seems a rather large amount.[*] The best soil for filtration appears to be a loose marl, containing hydrated iron oxide and alumina, but sand and even chalk produce excellent results. But in order that filtration shall be successful it is necessary that the amount of filtering material shall be large ; it must not be less than 1 cubic yard for 8 gallons of sewage in 24 hours,[†] and in the case of some soils must be more. If the drains are 6 feet below the surface, then an acre will contain 9680 cubic yards of filtering material, and at 8 gallons per yard an acre would suffice for 77,440 gallons. Crops may be grown on the land, and indeed it is desirable that they should be.

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[*] Many analyses are given in the First and Second Reports of the Rivers Pollution Commissioners, from which it appears that on an average the chemical processes remove 89·8 per cent. of the suspended matters, but only 36·6 per cent. of the organic nitrogen dissolved in the liquid. Mr Crookes' analyses show that the A B C process, when well carried out, removes all the phosphoric acid. Voelcker's analysis of the effluent water treated by the acid phosphate of alumina contains more ammonia than the original sewer water, less organic nitrogen by one-half, and less phosphoric acid ; it is pure enough to be discharged into streams.

[†] On the Downward Intermittent Filtration of Sewage at Merthyr-Tydvil, by T. J. Dyke, F.R.C.S. Eng.

When the filters are too small, they fail to do much good ; and Letheby has given analyses which prove that small filters may be nearly useless. It appears undesirable to use charcoal filters on this account, and all filtration through charcoal has been a failure. Spongy iron has been lately very strongly recommended.

Filtration may be downwards or upwards, but the former kind is much more efficacious. Upward filtration may be said to be now abandoned.

*Condition of the Effluent Water.*—When 5·6 gallons of sewage were filtered in twenty-four hours through a cubic yard of earth, it was found by the Rivers Pollution Commissioners that the organic carbon was reduced from 4·386 parts to ·734, and the organic nitrogen from 2·484 parts to ·108 parts in 100,000. The whole of the sediment was removed. Nitrates and nitrites, which did not exist before filtration, were found afterwards, showing oxidation.

### 6. *Irrigation.*[‡]

By irrigation is meant the passage of sewer water over and through the soil, with the view of bringing it as speedily as possible under the influence of growing plants. For this purpose it is desirable that the sewer water should be brought to the land in as fresh a state as possible. In some cases, as at Carlisle, carbolic acid in small quantities has been added to the sewage in its flow for the purpose of preventing decomposition, and the plan appears to be effectual. The sewer water is usually warmer than the air at all times, and will often cause growth even in winter.

The effect on growing plants, but especially on Italian rye-grass, is very great ; immense crops are obtained, although occasionally the grass is rank and rather watery. For cereals and roots it is also well adapted at certain periods of growth, as well as for market vegetables when the viscid parts are separated. When the sewer water permeates through the soil there occur—1*st*, a mechanical arrest of suspended matters ; 2*d*, an oxidation producing nitrification, both of which results depend on the porosity and physical attraction of the soil ; and, 3*d*, chemical interchanges. The last action is important in agriculture, and has been examined by Bischof, Liebig, Way,[*] Henneberg, Warrington,[†] and others. Hydrated ferric oxide and alumina absorb phosphoric acid from its salts, and a highly basic compound of the acid and metallic oxide is formed. They act more powerfully than the silicates in this way. The hydrated double silicates absorb bases. Silicates of aluminium and calcium absorb ammonia and potassium from all the salts of those bases, and a new hydrated double silicate is formed, in which calcium is more or less perfectly replaced by potassium or ammonium. Humus also forms insoluble compounds with these bases. Absorption of potash or ammonia is usually attended with separation of lime, which then takes carbonic acid.

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[*] At Merthyr-Tydvil 20 acres of land were divided into beds, which sloped towards the effluent drain by a fall of 1 in 150. The surface was ploughed in ridges, on which vegetables were sown ; the sewage (strained) passed from a carrier along the raised margin of each bed into the furrows. The effluent water was stated to be pure enough to be used for drink. Since 1872 these filter-beds, as well as 230 acres of other portions of the land, have been used as ordinary irrigation ground. The effluent water remains bright and pure. (Report on Town Sewage.)

[†] The Rivers Pollution Commissioners give a smaller amount, viz. 5⅗ gallons per cubic yard ; but some of their experiments seem to show that we must increase the amount. For example, the soil at Beddington was found by them to have a remarkable power of nitrification up to the extent of 7·6 gallons per cubic yard in twenty-four hours. But when this rate was doubled nitrification ceased, and the soil became clogged. The best soil experimented on (Dursley soil) containing 43 of silica and 18 of oxide of iron, purified 9·9 gallons in twenty-four hours per cubic yard. But as few soils would be so good, the limit of 8 gallons is selected in the text.

[‡] On the application of sewage to land many works have been published. Dr Corfield's work on the Treatment and Utilisation of Sewage, 2d edition, and the Report of the Committee of the British Association, 1872, give the best summary of the subject. Also the Report of the Committee on Town Sewage, 1876.

The soil must be properly prepared for sewage irrigation ; either a gentle slope, or a ridge with a gentle slope on each side of about 30 feet wide,[‡] with a conduit at the summit, or flat basins surrounded by ridges, are the usual plans. The sewer water is allowed to trickle down the slope at the rate of about 8 feet per hour, or is let at once into the flat basin. The water passes through the soil, and should be carried off by drains from 5 to 6 feet deep, and thence into the nearest water-course.

The sewer water should reach the ground in as fresh a state as possible ; it is usually run through coarse strainers to arrest any large substances which find their way into the sewers, and to keep back the grosser parts which form a scum over the land ; it is then received into tanks, whence it is carried to the land by gravitation, or is pumped up. The "carriers" of the sewer water are either simple trenches in the ground, or brick culverts, or concreted channels, and by means of simple dams and gates the water is directed into one or other channel as may be required. Everything is now made as simple and inexpensive as possible—underground channels and jets, hydrants, hose and jets, are too expensive, and overweight the plan with unnecessary outlay.

The amount of land required is, on an average, 1 acre to 100 persons ; this is equal to a square of 70 yards to the side, and will take 2000 gallons in twenty-four hours.

The sewer water is applied intermittently when the plants are growing ; but in winter it is sometimes used constantly, so as to store up nourishment in the soil for the plant-growth in the spring.[§]

The amount of sewer water which can be applied will vary with the kind of ground, the amount of rain, and the season of the year. In the year ending 1871, it appears that, on the Lodge farm at Barking, 622,324 tons of sewage were applied to 163 acres (nearly), or about 3800 tons per acre. In the sixteen months ending December 1872, the average quantity was 3342 tons per acre annually. On the most porous part of the farm as much as 960 tons have been applied in twelve hours.[*]

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[*] Journal of Royal Agricultural Society, vol. xi.

[†] Chemical News, May 1870. Warrington's paper gives a good resumé of the subject, and many original experiments, and can be consulted for full details.

[‡] This is the arrangement of Mr Hope's farm at Romford.

[§] See an interesting paper on the Utilisation of the Sewage of Paris, by Sandford Moore, B.A., Assist.-Surgeon, 4th Dragoon Guards (Medical Times and Gazette, June 1870). In the summer "arrosage" is practised : the land is ploughed in furrows and ridges, and the water is allowed to flow into the furrows, and not allowed to wet the vegetables which are planted on the ridges. In winter "colmatage" is had recourse to ; the ridges are levelled and the entire surface is submerged under sewage water. The sewers of Paris receive only a small part of the solid excreta (though most of the urine), but the fluid is highly fertilising. Precipitation with alum was also formerly had recourse to in Paris, but has now been abandoned.

For detailed information see the Report of the Prefecture of the Seine, "Sur l'assainissement de la Seine." An abstract is given in the Annales des ponts et Chaussées, and is translated by R. Manning, M.I.C.E., (E. and F. N. Spon.) 1876. Similar works are in process at Berlin and are described in the same paper. At Brussels, the Senne, during its passage through the city, is no longer used as the main sewer, and although the sewage is still poured into it at a lower point, it will ultimately be disposed of by irrigation.

### *Condition of the Effluent Water after Irrigation.*

When the sewer water passes over and not through the soil, it is often impure, and even suspended matters of comparatively large size (such as epithelium) have been found in the water of the stream into which it flows. It requires, therefore, that care shall be taken in every sewage farm that the water shall not escape too soon. Dr Letheby,[†] whose authority on such a question no one can doubt, rates the cleansing power of soil much lower than the Rivers Pollution Commissioners or the Committee of the British Association, and his analyses make it at any rate quite certain that the proper purification of the sewer water demands very careful preparation of the ground in the first instance, and constant care afterwards. But the chemical evidence of the good effect of irrigation is too strong to admit a doubt to exist, as will be seen from the following table.[‡]

*Table from the Report of the Rivers Pollution Commissioners.*

| Results of Irrigation. In parts per 100,000. | Percentage of dissolved Organic Pollution removed. | | Percentage of suspended Organic Pollution Removed. |
|---|---|---|---|
| | Organic Carbon. | Organic Nitrogen. | |
| On fallow land at Chorley (adhesive loam), | 62·3 | 70·2 | 100· |
| At Edinburgh (both sand and clay), . | 45·3 | 81·1 | 84·9 |
| Barking (gravelly soil), . . . | 65 8 | 86·2 | 100· |
| Aldershot (light sand), | | | |
| Best result, . . . . | 91 8 | 87·3 | 99·7 |
| Worst result. . . . . | 69·9 | 82·9 | 87·7 |
| Average result, . . . | 80·9 | 85·1 | 93·7 |
| Carlisle (light loam), . . . | 77·9 | 59·8 | 100· |
| Penrith (light loam), . . . | 75·0 | 77·2 | 100· |
| Rugby (adhesive soil), . . . | 72·3 | 92 9 | 96·0 |
| Banbury (principally clay , | | | |
| Best result, . . . . | 87·8 | 91·3 | 96·0 |
| Worst result, . . . | 64·1 | 80·1 | 90·8 |
| Average result, . . . | 76· | 85·7 | 93·2 |
| Warwick (stiff clay), . . . | 71·7 | 89·6 | 100· |
| Worthing (loam), . . . . | 42·7 | 83·5 | 100· |
| Bedford (light gravelly soil). | | | |
| Average result, . . . | 71·6 | 81·3 | 100· |
| Norwood (clay), | | | |
| Average result, . . . | 65·0 | 75·1 | 100· |
| Croydon (gravelly soil), | | | |
| Best result, . . . . | 73·2 | 93·2 | 100· |
| Worst result, . . . | 61·6 | 90·4 | 100· |
| Average result, . . . | 67·4 | 91·8 | 100· |

These results are much better than those of any chemical precipitant, the best result of the lime process giving a removal of only 65·8 per cent. of the organic nitrogen, and the best result of Sillar's (A, B, C) plan giving only a percentage of 58·9. They are not quite so good as the downward filtration plan, but the difference is not great.

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[*] Mr Morgan's Report, quoted in Food, Air, and Water, Dec. 1871.

[†] The Sewage Question, 1872, pp. 3–27.

[‡] The standard of purity which the effluent water should have has not yet been fixed. That proposed by the Rivers Pollution Commissioners, which is based on the method of analysis proposed by Dr Frankland, and which is not yet universally admitted, was as follows :—

### *Do Sewage Irrigation Farms affect the Public Health or Public Comfort?*

That sewage farms, if too near to houses and if not carefully conducted, may give off disagreeable effluvia, is certain; but it is also clear that in some farms this is very trifling, and that when the sewer water gets on the land it soon ceases. It is denied by some persons that more nuisance is excited than by any other mode of using manure. As regards health, it has been alleged that these farms may—1*st*, Give off effluvia which may produce enteric fever, or dysentery, or some allied affection; or, 2*d*, Aid in the spread of entozoic diseases; or, 3*d*, Make ground swampy and marshy, and may also poison wells, and thus affect health.

The evidence of Edinburgh, Croydon,* Aldershot, Rugby, Worthing, Romford, the Sussex Lunatic Asylum,† is very strong against any influence in the production of typhoid by sewage farms' effluvia. On the other hand, Dr Clouston's record of the outbreak of dysentery in the Cumberland Asylum (see page 131), is counter-evidence of weight, and so is one of the cases noted by Letheby,‡ of typhoid fever outbreak at Copley, when a meadow was irrigated with the brook water containing the sewage of Halifax.

The negative evidence is, however, so strong as to justify the view that the effluvia from a well-managed sewage farm do not produce typhoid fever or dysentery, or any affection of the kind. In a case at Eton, in which some cases of enteric fever were attributed to the effluvia, Dr Buchanan discovered that the sewer water had been drunk; this was more likely to have been the cause.

With regard to the second point, the spread of entozoic diseases by the

*Standard of Rivers Pollution Commissioners. Maximum of Impurity permissible in* 100,000 *parts by weight of the liquid.*

| Dry mineral matter in suspension. | Dry organic matter in suspension. | Colour. | In Solution. | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Organic carbon. | Organic nitrogen. | Any metal except Calcium, Magnesium, Potassium, or Sodium. | Arsenic. | Chlorine. | Sulphur as $SH_2$, or sulphate. |
| 3 | 1 | Shown in a stratum of 1 inch in a white plate. | 2 | ·3 | 2 | ·05 | 1 | 1 |

A certain degree of acidity or alkalinity is also ordered not to be surpassed. In the discussions on the Public Health Bill in the House of Commons, this standard, which had been embodied in the Bill, was struck out, and the standard is left to be hereafter determined. (No standard is given in the Rivers Pollution Act of 1876.) The objection to the plan is not merely the doubt about the substances represented by organic carbon or nitrogen, but also because the standard does not take into consideration the volume of water into which the foul water flows. The Thames Conservancy Commissioners adopt a standard for effluent sewage as follows:—

| | Must not exceed in 70,000 parts. |
|---|---|
| Suspended matters, | 3 parts. |
| Total solids, | 70 ,, |
| Organic carbon, | 2 ,, |
| ,, nitrogen, | 0·75 ,, |

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* Carpenter, various papers and essays on this subject drawn from the experience of Croydon Sewage Farm.

† Dr J. W. Williams, Brit. Med. Journal, 11th May 1872.

‡ The Sewage Question, p. 190.

carriage of the sewer water to the land, has been thought probable by Cobbold, though as solid excreta from towns have been for some years largely employed as manure, it is doubtful whether the liquid plans would be more dangerous. The special entozoic diseases which, it is feared, might thus arise, are Tapeworms, Roundworms, Trichina, Bilharzia, and Distoma hepaticum in sheep. Cobbold's latest observations show that the embryos of Bilharzia die so rapidly that, even if it were introduced into England, there would be little danger. The Trichina disease is only known at present to be produced in men by the worms in the flesh of pigs which is eaten, and it seems doubtful whether pigs receive them from the land. There remain, then, only Tapeworms and Roundworms for men and Distoma hepaticum for sheep to be dreaded. With regard to these, the evidence at present is negative ; and though much weight must be attached to any opinion of Cobbold's, this argument against sewage irrigation must be admitted to want evidence from experience.*

The third criticism appears to be true. The land may become swampy, and the adjacent wells poisoned, and disease (ague† and perhaps diarrhœa and dysentery) be thus produced. But this is owing to mismanagement, and when a sewage farm is properly arranged it is not damp, and the wells do not suffer.

### *Objections to Sewers.*

The main objections are as follows :—

1. That as underground channels, connecting houses, they allow transference of effluvia from place to place. The objection is based on good evidence, but it must be said in reply that, if proper traps are put down, and if air-disconnection, in addition, is made between the outside drains and the house pipe, such transference is impossible. The objection is really against an error of construction, and not against the plan as properly carried out. Besides, the objection is equally good against any kind of sewer, and yet such underground conduits are indispensable.

2. That the pipes break and contaminate the ground. This is a great evil, and it requires care to avoid it. But such strong pipes are now made, that if builders would be more careful to make a good bed, and to connect the joints firmly, there would be no danger of leakage, as far as the pipe drains are concerned, and not much damage of the main brick sewers. At great depths, also, the pressure of the soil water will rather cause entry than exit from the sewers.

3. That the water supply is constantly in danger of contamination. This also is true, and as long as overflow pipes from cisterns are carried into sewers, and builders will not take care to make a complete separation between water pipes and refuse pipes, there is a source of danger. But this is again clearly an error in constructive detail, and is no argument against a proper arrangement.

## ON THE INFLUENCE THE CONSTRUCTION OF SEWERS HAS HAD ON THE DEATH RATE OF TOWNS.

Reference has already been made to the possibility of sewers being the channels by which enteric fevers and cholera have been propagated from house to house, and from which emanations, causing diarrhœa and other complaints, may arise. Admitting the occasional occurrence of such cases, it remains to be seen whether the sanitary advantages of sewers may not greatly counterbalance their defects. The difficulty of proving this point statistically consists in the number of other conditions affecting the health of a town in addition to those of sewerage. Dr Buchanan[*] has, however, given some valuable evidence on this point, which has been well commented on by Mr Simon. He inquired into the total death rate from all causes, and the death rate from some particular diseases, in twenty-five towns before and after sanitary improvements, which consisted principally of better water supply, sewerage, and town conservancy. The general result is to show that these sanitary improvements have resulted in a lowering of the death rate in nineteen out of twenty-five towns, the average reduction in these nineteen cases being 10·5 per cent. The reduction in typhoid (enteric) fever was extremely marked, and occurred in twenty-one towns out of twenty-four, the average reduction being 45·4 per cent. in the deaths from typhoid. In three cases there was an augmentation of typhoid fever, but this was manifestly owing to imperfection in the sewerage arrangements; and these cases afford excellent instances of the unfavourable part badly-arranged sewers may play in this direction.[†]

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* Cobbold has since withdrawn his objection.

† There is no ague or any other disease traceable to the sewage irrigation at Craigentinny, near Edinburgh.

Diarrhœa has been also reduced, but not to such an extent; and in some towns it has increased, while typhoid fever has simultaneously diminished.[‡] But the term diarrhœa is so loosely used in the returns as to make any deduction uncertain. Cholera epidemics Dr Buchanan considers to have been rendered "practically harmless." The immense significance of this statement will be at once appreciated. Whether the result is owing solely to the sewerage or to the improved water supply, which is generally obtained at the same time, is not certain. Phthisis, which Dr Buchanan and Dr Bowditch[§] find to be so much influenced by dampness of soil, does not appear to have been affected by the removal of excreta *per se*, at least towns such as Alnwick and Brynmawr, which are thoroughly drained, show no lowering in the phthisical mortality. Nor could Dr Buchanan trace any effect on the other diseases of the lungs.

As far as can be seen, the effect of good sewerage has therefore been to reduce the general death rate, especially by the reduction of deaths from typhoid and from cholera (and in some towns from diarrhœa), but partly, in all probability, by general improvement of the health. The action has been, in fact, very much in the direction we might have anticipated.[||]

It may be observed, that this inquiry by Dr Buchanan does not deal with the question as between sewers and efficient dry methods of removing excreta (on which point we possess at present no evidence), but between sewerage and the old system of cesspools.

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[*] Ninth Report of the Medical Officer to the Privy Council, p. 12 *et seq.* and p. 40.

[†] See the case of Worthing (p. 45), for a striking instance of the spread of typhoid through sewers.

[‡] Virchow has called attention to the lessening of typhoid.

[§] Ninth and Tenth Reports of the Medical Officers to the Privy Council. See especially Dr Buchanan's Report in the last-named work, p. 57. See also chapter on SOIL, p. 331.

[||] The case of Dantzig is a good illustration. In the nine years from 1863 to 1871, before the town was drained and supplied with pure water, the death-rate was 36·9 per 1000, almost the same as in the previous 38 years (1825–62), 36·5. In the five years, 1872 to 1876, when the new drainage and water-works were in full operation, it was only 28·5; thus there was an apparent saving of 3156 lives during that period. Cholera has attacked Dantzig eleven times, generally severely, and in 1866 it killed 1098 persons. It returned in 1873, but was unable to gain a footing, only 91 persons falling victims to it. Children being usually the most delicate indicators of disease, it was found that in the first period, before the drainage, there died out of every 1000 inhabitants 13·04 children; in the second period, after the drainage, only 10·77; or the lives of 855 children were saved during the second period. (Danzige Zeitung, quoted in Deutsche Vierteljahrschaft f. öff. Ges. 9ter. Bd. 2tes. Hft. p. 350).

## Modifications of the Wet Method of Removing Excreta.

### *The Separate System.*

By this term is meant the arrangement which carries the rain-water in separate channels into the most convenient water-course.* Mr Ward's celebrated phrase "the rain to the river, the sewage to the soil," is the principle of this plan. Its advantages are that the sewers can be smaller; that the amount of sewer water to be dealt with at the outflow is much less in quantity, more regular in flow, and richer in fertilising ingredients, and is, therefore, more easily and cheaply disposed of. The grit and *débris* of the roads also are not carried into the sewers; and the storm waters never flood the houses in the low parts of the town.

The disadvantages are, that separate channels and pipes have to be provided for the rain; that the rain from all large cities carries from roofs and from streets much organic *débris* which pollutes streams, and that the scouring effect of the rain on sewers is lost.

The adoption of one or other system will probably depend on local conditions. If a town in Europe lies low, and it is expensive to lift sewage; if land cannot be obtained; or if the natural contour of the ground is very favourable for the flow of rain in one direction, while it is convenient to carry the sewage in another, the separate system would be the best. So also in the tropics, with a heavy rainfall and a long dry season, the providing of sewers large enough to carry off the rain would be too expensive for all except the richest cities, and the disposal of the storm water would be difficult.

In all cases in which rain enters the sewers, some plan ought to be adopted for storm waters.† If irrigation is the plan carried out, the sewer water becomes so dilute and so large in quantity in storms, that the application to land is usually suspended, and the sewer water is allowed to pass at once into streams.

In this way the evil which irrigation is intended to prevent is produced, though, doubtless, the sewer water is highly dilute. In London, the storm waters are allowed to flow into the Thames, special openings being provided.

In many of the continental cities, the fluid and solid excreta fall into a receptacle with perforated sides or bottom, so that the fluid part drains away and the solid is retained, and is removed from time to time. Such a plan may keep the sewers free from deposit, but has the great disadvantage of retaining large collections of excreta close to and in many cases immediately under or in the cellars of houses, and no ventilation can entirely remove all effluvia.

An improvement on this plan is a method proposed by Mr Chesshire, of Birmingham. He places outside the house, in any place where access is easy, a comparatively small box, connected by trapped pipes with the water-closet at one end, and the sewer at the other. The lid of the box is fixed down with concrete or putty, so that the access of air is stopped. Across one end of the box is a single or double strainer, which allows the urine and water to pass, but retains the solids. From time to time the box is lifted out, carted away, and another is inserted. The solid matter is almost free from odour, as the limited access of air hinders putrefaction.

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* On this subject the works of Mr Menzies, who first described this plan, and of Colonel Ewart, R.E. (Report on the Drainage of Oxford, Eton, Windsor, and Abingdon, 1868), will be found very useful.

† Plans for this purpose are figured and described in the works on Sanitary Engineering, by Baldwin Latham, and Bailey Denton.

The difficulty about this plan is the occasional blockage of the strainer, so that the solid matters remain wet, and may soon fill the box, so that the lid may be forced off. The liquid which flows from the box is of course highly impure with excreta, but the retention of the solids prevents blockage of the sewers. At present it can only be said that this plan has not been yet practically established on the large scale, but is well worthy of extended trial, particularly in cases where the difficulties of irrigation are great.

### *Water-Closets and Water-Troughs.*

*Water-Closets.*—The pan of the closet is usually a cone in earthenware (which is better than metal), and a syphon or flap valve below. In addition, there are numerous contrivances for flushing the pan and syphon, and for preventing the escape of the air from the soil-pipe into the house.* The soil-pipe is usually of cast lead; but both lead and iron are easily eaten through, as shown by Dr Fergus, and earthenware pipes, if strong and well joined, would be preferable.†

The points to be looked to in examining closets are—1*st*, That the pan is nearly a cone, and not a half circle with a flat bottom; 2*d*, That the amount and force of water is sufficient to sweep everything out of the syphon; 3*d*, That the soil pipe is ventilated below the syphon, by being carried up to the top of the house; 4*th*, That the junction of syphon and soil-pipe and the lengths of the soil-pipe are perfect.

With respect to water, a pipe from the house cistern frequently leads to the closet; but if so, there is some danger of gas rising through the pipe. There should be a special small cistern for the use of the closet. What are termed water-waste preventers are now commonly used, either fed by a cistern or by constant supply. They are boxes which are emptied by a valve into the pan, and are then slowly refilled. There are many kinds, and most of them discharge from ¾ to 1½ gallon at a time. The amount should not be less than a gallon, and the fall should not be less than 3 or 4 feet, so as to insure thorough scouring of the soil-pipe.‡ In an ingenious arrangement by Mr Commons (based, I believe, on an idea of Mr Holland's), the water is stored in an inverted iron bottle, the air in which is compressed by the water. When the valve is opened, the compressed air drives down the water with great force.

The ventilation of the soil-pipe is a matter of importance, as the water from the pan suddenly displaces a large body of foul air, which rises through the syphon as the water flows. A small pipe below the syphon, running to the outer air and discharging at some point far from windows, seems the best arrangement. But there ought always to be another opening to the air, from which air may be drawn, so as to create a current. This may be done, either by a grated trap below, or (as in Banner's plan) by drawing air from another shaft carried up the house. The currents in the two shafts are determined by reversed cowls.§

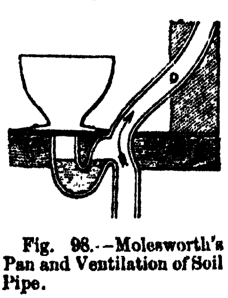

Fig. 98.—Molesworth's Pan and Ventilation of Soil Pipe.

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* Mr Eassie's work, "Healthy Houses," gives a good account of the various kinds of closets.

† In his work on Sanitary Arrangements for Dwellings, Mr Eassie does not approve of earthenware pipes, preferring the strongest cast lead to any other.

‡ The Army Sanitary Committee (On Sanitary Appliances, Blue Book, 1871, p. 17), state that the amount of water used in the water-closets in the army is, for Green's closet, between ½ gallon and 1 gallon for each time of use; Underhay's, Lambert's, and the pan-closet, from 1 to 1½ gallon; and for Jenning's closet usually the same, or in some stations 3 gallons.

§ For the outgoing pipe, especially if there be merely a grating below as an inlet, a cowl is not absolutely necessary, but if required, various kinds are applicable. Besides Banner's, that of Dr Macdonald and also Boyle's might be used.

Dr Taylor of Anerley has invented a trap on this plan, and in which a good scouring effect of water is secured.

Mr Jenning's closet, with plug and water trap, has the advantage of effectually preventing the regurgitation, but the plan is rather expensive.

The position of the closet is a matter of great moment. If possible, it should always be in an outbuilding, or a projection, with thorough ventilation between it and the house. In two-storied buildings it might be put in a small third story in the roof, and well ventilated above. The windows in a closet ought always to open quite to the ceiling.

In all cases, a tube should pass from the top of the closet to the outer air; and, if the closet is in a bad situation, should be heated by a gas jet.

It is a bad plan to have the pull-up handle covered by the lid;[*] it should be able to be pulled up when the lid is shut, or the shutting of the lid should open the water-waste preventer cistern.

The plan of placing closets in the basement should be entirely given up; closet air is certain to be drawn into the house.

*Water-Troughs or Latrines.*—These are very strong earthenware or cast-iron receptacles, which are about half full of water. The excreta drop into the water, and once or twice a day a valve is raised, and the water and excreta pass into a drain. In Liverpool, where excellent water-troughs are in use, there is a receptacle into which fall bits of bricks, towels, or other things which are thrown in, so that they are stopped and fished out when the trough is emptied, and do not pass into the drain. The amount of water in the water latrines used in some barracks is about 5 gallons per head daily, so that the plan is not economical of water, but, as it avoids all loss by the dripping in closets, there is probably no great excess of expenditure. It is a good plan to have a flexible hose attached to the water pipe, so as to wash thoroughly the seats and partitions every day.

The chief objection to this plan is the labour which is necessary to empty the trough; but the plan saves expenditure in repairs to water-closets, and in this respect there is some compensation.[†]

In judging of the value of a water-trough, the amount of water, the surface exposed to evaporation, and the completeness of the flushing, are the points to look to.

## DRY METHODS.[‡]

The use of sewers and removal by water are in many cases impracticable. A fall cannot be obtained; or there is insufficient water; or the severity of the climate freezes the water for months in the year, and removal by its means cannot be attempted. Then either the excreta will accumulate about houses, or must be removed in substance daily or periodically. Even when water is abundant, and sewers can be made, many agriculturists are in favour of the dry system, as giving a more valuable fertilising product; and various plans are in use.

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[*] In Dr Aldridge's patent the handle cannot be pulled up until the lid is shut down; there is also arrangement for carrying off foul gas by means of a pipe communicating with the outer air, the lid itself being air-tight round the rim of the seat.

[†] In the army two kinds of latrines (Macfarlane's, of cast-iron, and Jenning's of earthenware) have been in use for about fifteen years. The Army Sanitary Committee (On Sanitary Applications introduced into Barracks, Blue Book, 1871, p. 14) state that out of 183 barracks only 53 have been charged with repairs, and the average expenditure on these 53 has been 12s. per barrack annually for Macfarlane's, and 18s. 9d. per barrack for Jenning's latrine, and nearly the whole of these expenses have been caused by articles thrown carelessly into the latrines.

[‡] On the dry methods of removal a very good paper has been published by Dr Buchanan and Mr Radcliffe (Twelfth Report of the Medical Officer to the Privy Council, 1870, pp. 80 and 111); also another by Mr Netten Radcliffe, Report on certain means of preventing Excrement Nuisances in Towns and Villages (New Series, No. 2, 1874).

It is not necessary to consider here the employment of cesspools, deadwells, &c., as such plans must be considered quite unsanitary, and should be invariably discontinued. If excreta are ever allowed to accumulate, it should be in properly prepared receptacles, and after admixture with deodorants.

### *Removal without Admixture.*

In some cases, the solid and liquid excreta pass into boxes or tanks, which are emptied daily, or from time to time, and the sewage is at once applied to land without further treatment. In Glasgow, the excreta from one part of the town, containing 80,000 people, are now removed every day without admixture, except with the garbage from the houses, and are sent long distances at a profit.* If the removal can be made daily, the plan is a good one; the manure should not be applied in the immediate neighbourhood of dwellings, and the Barrack Commissioners have ordered that it shall not be put on land nearer barracks than 500 yards.

In some towns in the North of England (Salford, Halifax, Nottingham), the receptacles are lined with some absorbent material (refuse of cloth manufactures) intended to absorb the urine (Goux system); in other cases the urine is carried off by a pipe into a drain; the intention being, in both cases, to make the fæcal matter drier, and to delay decomposition.

In others, the soil being removed daily, or at short intervals, is taken to a manufactory, and there subjected to manipulations which convert it into a manure.

Under the term "Poudrette," manufactories of this kind have been long carried on in France, though they are said not to be very profitable.† At present, however, a portion of the nitrogen of the urea is converted into ammonia, and is united with sulphuric acid, and comes into the market as sulphate. In England, also, there have been several manufactories, such as the "Hyde Patent Manure Eureka Company," who reduced the soil to one-seventh of its bulk by the application of heat, and obtained a good manure. Actions for nuisance, on account of the effluvia, and the expense of the process, caused, however, the company to wind up.

There have been great discussions as to the salubrity of the French poudrette manufactories, and the evidence is that they are not injurious to the workmen or to the neighbourhood, although often incommodious. But the poudrette can take on a kind of fermentation which renders it dangerous, and Parent-Duchâtelet has recorded two cases of outbreaks of a fatal fever (typhoid ?) on board ships loaded with poudrette. In the case of the Eureka Company no bad effect was produced on the health of the men.

### *Admixture with Deodorising and Anti-putrescent Substances.*

Usually, however, some deodorising substance is mixed with the excreta before they are removed from the house, and they are then at once applied to land without further preparation. Mr Moule's advocacy of the use of dried earth has brought into prominent notice the great deodorising powers of this substance, and perhaps no suggestion of late years has had more important consequences. The various substances employed to prevent odour and decomposition are as follows :

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* At Carlsruhe, Mannheim, Rastadt, and Bruchsal the excreta are removed in boxes holding about 116 cubic feet (Prussian) every evening. From an experience of eighteen years (1851-1868), the excreta of 6351 men (mean strength) returned 7628 florins per annum, or about 1s. 11d. English money per head. In Bruchsal it was 1s. 1d., and in Mannheim 2s. 6d. per head. This rich manure has converted the sandy wastes into fertile corn-fields.

† Nearly all the solid excreta of Paris are dealt with in the same way, at the great depôt of Clichy-Varenne.

1. *Coal and Wood Ashes.*—This is a common practice in the north of England, and closets are made with hinged flaps or seats, so that the coal ashes may be thrown on the sewage. Sometimes screens are used, so that the large cinders are held back, and can be again used for firing. In some towns there are receptacles (middens) intended both for excreta and ashes ; sometimes these are cemented, but are usually porous, and there may be a pipe leading into a sewer so as to dry them. The midden system is a bad one ; even with every care, the vast heaps of putrefying material which accumulate in some of our towns must have a very deleterious influence on the health, and the sooner all middens are abolished the better. The deodorising effect of coal ashes is very slight. The mixture of coal ashes and excreta usually finds a sale, but the profit is much greater if no ashes are mixed with it. Wood ashes are far more powerful as deodorisers, but it is not easy in this country to have a proper supply.

2. *Charcoal.*—There is no better deodoriser than charcoal.* Animal charcoal is too expensive, and peat charcoal is cheaper ; according to Danchell, 3 ounces of peat charcoal are equal to 1½ ℔ of earth ; and this author states that the cost of charcoal for a family of six persons would only be 1s. 6d. per month. A plan has been proposed by Mr Stanford,† and is in use at Glasgow, which may obviate the difficulty of price. Mr Stanford proposes to obtain charcoal from seaweed ; the charcoal is cheap, and remarkably useful as a deodoriser. After it has become thoroughly impregnated with fæces and urine, the mixture is re-carbonised in a retort, and the carbon can be again used ; the distilled products (ammoniacal liquor, containing acetate of lime, tar, gas) are sufficient to pay the cost, and it is said even to give a profit.

The closet used with this carbon is, in principle, similar to Moule's earth closet, with various improvements for more thoroughly mixing the charcoal and sewage.

The advantages claimed for Mr Stanford's process are the complete deodorising effect ; the small amount of charcoal required as compared with dry earth (three-fourths less required) ; the value of the dry manure, or of the distilled products, if the mixture is reburnt ; and, in the last case (burning), the complete destruction of all noxious agencies. In using it the mixed charcoal and sewage may be stored for some months without odour in some convenient receptacle outside, but not under the house ; and Mr Stanford states that all the house urine can be also allowed to flow into this receptacle. The reburning of the mixture can be in a gas retort, or a special retort is built for the purpose ; the charcoal left in the retort is returned to the house.

3. *Earth.*—Since the Rev. Mr Moule pointed out the powerful deodorising properties of dried earth, many different closets have been proposed.

Mr Moule's earth closet consists of a wooden box, with a receptacle below, and a hopper above, from which dried earth falls on the sewage when the plug is pulled up. The earth is previously dried, and about 1¼ to 1½ ℔ of the dried earth per head daily is the usual allowance. For a single house, the earth can be dried over the kitchen fire ; but if a village is to be supplied, a small shed, fitted with tiles, below which smoke pipes from a small furnace pass, is required. The earth used in the closet is sufficient to deodorise the solid excreta, and the portion of the urine passed with them ; but the rest of the urine and the house water has to be carried off in pipes, and disposed of in some other way. The receptacle is emptied from time to time, and the mixture is stored until it can be applied to land.

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* At Kreilingen in Holland, a pail system is in use, where charcoal is employed made from burning town refuse. It appears to yield a product of sufficient value to pay itself.

† Chemical News, June and October 1869, and Feb. 1872.

The advantages of this plan are obvious; its disadvantages are the necessity of collecting, and drying, and storing the earth, which for cottagers who have little space, and possibly no means of getting earth, is a serious matter. The supply of dried earth to large towns is almost a matter of impossibility, so large is the amount required.[*] Again, the attention necessary to prevent the house water being thrown in, and to remove the soil at sufficiently short periods, sometimes militate against the success. To obviate these disadvantages, some modifications have been introduced into Moule's closet: one side of the receptacle may be covered with a grating, leading to a pipe, so that all fluids drain away, and the house water can be thrown in. In another plan, as in Taylor's improved closet, the urine is carried away without mixing at all with the solid excreta. Sometimes the urine thus separated is led into another box of earth, and is thus more easily disposed of, if there are no means of taking it entirely away; or it is passed into a tank, and then used as liquid manure. In another modification (Möser's), a partition along the front holds some absorbent substance (sawdust, straw), into which the urine passes, and the solids are thus kept dry. This separation of the urine and solids certainly appears to be an improvement. Dr Carpenter of Croydon reports well of these closets (Baily Denton, *op. cit.* p. 102).

The best kind of earth is clay, marl, and vegetable humus; when dried, the clay is easily powdered. Chalk and pure sand are of little use.

The earth system is coming into great use in India, and is carried out with great attention to detail. In those European stations where water is not procurable, Mr Moule's invention has been a boon of great value, and I have been told by medical officers that nothing has been done in India of late years which has contributed so much to the health and comfort of the men.[†] The plan of separating the urine from the fæces has been strongly advocated by Dr Cornish of Madras, and would no doubt be attended with great advantages in India, if there are means of disposal of the urine. The chief difficulty in the European barracks in India is felt during the rainy seasons, when the mixed excreta and earth cannot be kept sufficiently dry.

In the case of natives of India, however, a serious difficulty arises in the use of the earth system, in consequence of the universal use of water for ablution after using the closet. Every native takes with him a small vessel holding 10 to 20 ounces of water, so that a large amount of fluid has to be disposed of. The usual earth closet does not suffice for this. Mr Charles Turner, C.E., of Southampton, has contrived a closet suitable for the native family;[‡] it is unfortunately too costly, and possibly a simple iron box, with a pipe to carry off the urine and ablution water, would be better suited for the poorer classes.

It appears from the observations of Mr Fawcus, at the jail of Alipore, that more earth must be used for vegetable than for animal feeders; the experiments gave 5·1 ℔ avoir. (2½ seers) of undried earth for the daily evacuation of a vegetable-feeding Hindoo. The urine discharge (2 ℔) required 8·2 ℔ of earth. The earth was efficacious in proportion to the vegetable organic matter or humus. In the experiments in this country the clayey matters (silicates of alumina) have seemed to be chiefly useful. In Indian jails and some cantonments the trench system is used; shallow (1 to 1½ foot deep) trenches are dug in a field, and earth is thrown over the excreta; when the trenches are full, the whole is ploughed up, and vegetables are at once planted, trenches being dug elsewhere; after two or three crops this portion of the field may be used again. Great importance is attached to the early and repeated cropping of the ground.*

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[*] For workhouses, prisons, barracks in country places, where there is plenty of labour, and no difficulty in obtaining and afterwards of disposing of the earth, the plan is almost perfect. So also for small villages, if some central authority arranges for the supply of earth, and for the removal of the used soil. For a good statement of the advantages of the earth system, see Dr Hawksley's paper in the Report of the Leamington Congress on the Sewage of Towns. The British Sanitary Co. has a good form of this closet.

[†] An account of the Bengal arrangements will be found in the 2d edition of this work, p. 329. I have now omitted it, as the plans are being much altered.

[‡] This was done at the suggestion of Dr Niven of Bombay. Mr Turner's closet is described and figured in my report on Hygiene for 1867, Army Medical Report for 1866, published 1868, vol. viii. p. 307.

4. *Deodorising Powders.*—Instead of charcoal or earth, M'Dougall's or Calvert's carbolic acid powders may be used, and this plan has been largely adopted in some Indian stations. A comparatively small quantity is required, but the smell of the carbolic acid and the cost are somewhat against the plan. Dr Bond's preparations of Terebene, viz., the Terebene powder, Cupralum, Ferralum, &c., are very efficacious and have a pleasant odour. Langton-Jones' Universal Disinfecting Powder is inodorous, but not very powerful.

5. Sawdust mixed with sulphuric or carbolic acid. I found the mixture of sulphuric acid and sawdust to have little efficacy; the carbolic acid has the disadvantage of the odour which adheres to the clothes. Chloralum powder is also mixed with sawdust, and is moderately efficacious.

6. In Germany, Süvern's deodoriser (a mixture of lime, magnesium chloride, and coal-tar) is much used. The Müller-Schür deodoriser is composed of 100 ℔ of lime, 20 ℔ of powdered wood charcoal, 10 ℔ of peat powder or sawdust, and 1 ℔ of carbolic acid containing 60 to 70 per cent. of real acid. After mixing, the mass is put under cover for a night to avoid any chance of self-combustion, and when it is dry it is packed in barrels. Lueder and Leidloff's powder, consisting of ferric sulphate, ferrous sulphate, calcium sulphate, and a little free sulphuric acid, is also much used. It is moderately successful.

### *Arrangement of Closets on the Dry Plan.*

As the excreta after being mixed with the deodoriser are in most cases kept for some days or even weeks close to the house, the same rules as to position and construction of closets should be employed as in the case of water-closets. The closet should never be in the basement, but in the roof, or better still in a detached building or semi-detached, and with thorough ventilation between it and the house; there should be a pipe leading at once to the outer air from the closet, and one from the receptacle.

The receptacle itself is usually movable; but if not, it should be most carefully cemented so that no leakage may occur.

With these precautions no odour will be perceived; but it is still very desirable that the removal of the soil should be as frequent as possible. In country houses there is no difficulty, but in towns the removal can seldom be more frequent than once a week, and often is only once a month.

The forms of the closet itself are numerous. Those applicable to the earth plan have been already noticed. Colonel Synge, R.E., has patented a closet for Mr Stanford's charcoal process (the Alver appliance for dry deodorants). In Germany and the north of Europe, where the dry removal, but without admixture with deodorant powders, is in much use, there are various closets in which the urine and fæces are separated.* The "air-closet" of Mehlhouse is said to be a good arrangement for houses. The urine runs into a porcelain funnel fixed on the front wall of the pan, and then into an iron vessel, from which it can readily be removed through a valve ; the solids fall into an iron receptacle at the back part of the pan. A discharge tube passes from the back and top part of this receptacle into a chimney. Two openings in the front wall, which can be closed by valves, can be used as inlets for the air. If a hopper with charcoal or dried earth were attached to this closet, it would be almost identical with Taylor's improved closet.†

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* Two objections have been made to the dry earth system: 1. It is almost impossible to get rid of a certain amount of smell, even with deodorants. 2. The product is not very valuable, according to Dr Gilbert's analysis, not so valuable as good garden mould, even after the earth has been twice used. The chief value is therefore a sanitary one.

### *Carbonisation.*

In 1869, Mr Hickey‡ of Darjeeling (Bengal Presidency) proposed to carbonise the sewage in retorts, either with or without previous admixture with charcoal. Almost at the same time Mr Stanford § proposed the plan already referred to, of the addition of sea-weed charcoal, and subsequent distillation.

In India the difficulty of obtaining a remunerative price for the ammoniacal products, and the large cost of the apparatus necessary for working the plan, has been unfavourable to its success. Dr Macnamara of Calcutta gives the following analyses of the products of the carbonisation :—*1st*, Gas (viz., hydrogen, 35·36 ; marsh gas, 31·28 ; olefiant and other heavy hydro-carbons, 2·4 ; carbonic oxide, 21·74 ; carbonic acid, 9, and a trace of phosphoretted hydrogen in 100 parts). *2d*, Tar-like stuff, the so-called "light-oils." *3d*, Ammoniacal liquid. *4th*, Residuum of animal charcoal, which rendered inodorous an equal weight of excreta. About 120 ℔ of coke were used to burn ½ ton of the mixed excreta. Carbonisation is now being tried in this country, and may possibly be commercially successful. Experience only can show if it is so, but if it will return a profit, there can be no question that it is an excellent plan in a purely sanitary point of view. The chief money difficulty in the process is the large amount of water which has to be driven off, which greatly increases the expense.

In Manchester Fryer's patent method is in operation, and it is now being applied, in whole or in part, at Birmingham and at Leeds. It consists of a Destructor, which reduces to slag all the more bulky town refuse, such as cinders and ashes, broken earthenware and glass, which cannot be dealt with except by being accumulated in a rubbish heap. This slag is ground, mixed with lime, and sold as mortar. The apparatus is so arranged that none of the heat is lost, while the heated products of combustion pass over fresh portions of material and prepare it for combustion. The mass is reduced in bulk to one-third. Other refuse, such as condemned food, vegetable garbage, street sweepings, and the like, are reduced to charcoal in another apparatus called the Carboniser. The carbon thus produced is used for disinfecting purposes, for decolorising the waste water from factories, &c. The excreta proper it is proposed to collect in pails and reduce to small bulk, by drying in a closed apparatus, called the Concretor; the ammonia being fixed by the sulphuric acid fumes produced by the other processes. By this means the contents of the pails are reduced to one-twelfth, and a valuable manure obtained, which may be either in the form of poudrette or mixed with a little charcoal.

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* Roth and Lex (*op. cit.* p. 454) give a good description of these. See also for some good remarks, Pettenkoffer's paper on the Sewerage of Bâle (Zeitsch. für Biologie, band iii. p. 273).

† Dr Bond has also invented a good form of self-acting closet, which separates the urine and fæces. At Manchester and Salford the cinder-sifting closet of Mr Morrell is in use.

‡ The Carbonisation or Dry Distillation System of Conservancy, by W. R. S. Hickey, C.E. ; with a note on Dry Sewage, by F. J. Mouat, M.D., Darjeeling, 1869.

§ A Chemist's View of the Sewage Question, Chemical News, June to October 1869.

### *The Pneumatic Air Plan*[*] (Aspiration Plan).

A Dutch engineer, Captain Liernur, proposed some few years since an entirely novel plan. No water or deodorising powders are used; the excreta fall into a straight earthenware pipe, leading to a smaller iron syphon pipe, from which they are extracted periodically by exhaustion of the air. The extracting force, which can be used (by an air-pump worked by a steam-engine), is said to be equal to a pressure of 1500 ℔ per square foot, which is sufficient to draw the excreta through the tubes with great rapidity. The plan has been tried on the small scale at Prague, Rotterdam, Amsterdam, Leyden, and Hanau, also at Brünn, Olmutz, and St Petersburg, and the opinions concerning it are very various. In Prague the judgment is on the whole unfavourable; in Hanau the report of Virchow, Marggraf, and Hacker,[†] is also not very much in favour of the plan. While in some of the tubes the action was satisfactory, in others there were portions of fæcal matter adhering to the sides, and in one tube there was reflux of offensive gas. A report on the same plan by a deputation from Frankfort is more favourable.[‡] In Amsterdam, the Liernur system has been in use in two streets since November 1871, and in Leyden since September 1871.[§] In Amsterdam the opinions are doubtful; some reflux of gas and some adherence of fæcal matters to parts of the tube is noted, and in the syphon all observers agree that some portion of fæces and urine remains. Care on the part of inhabitants, and washing some of the tubes with a small quantity of water, appears to be sometimes necessary; and in times of epidemics disinfection must also be used. The opinions of Schröder and Lorent appear finally to be that, while the system can hardly be recommended for hospitals, and in fact is perhaps not to be generally recommended, there may be localities where it can be advantageously used, as in low-lying marshy places, where irrigation of water sewage cannot be used. It is agreed by all that it cannot render sewers unnecessary. I have not seen this system in operation, but the effect produced upon my mind by reading the reports is, that it is less simple and less efficacious than the English plan of dry removal after admixture with deodorants, but that it is more easily worked than was anticipated.[||]

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[*] The Sewage Question, by F. C. Krepp, London. 1867. This book was written for the purpose of bringing the Liernur plan before the public, and some parts of it must be taken with limitation.

[†] Deutsche Vierteljahrs. für öffentl. Gesundsheitspfl. band iii. p. 313 (1871).

[‡] Ibid. band iii. p. 312.

[§] Report of Kauff and Esser in Deutsche Viertelj, für off. Gesundsheitspfl. band iv. p. 316. These gentlemen were sent from Heidelburg to investigate the plan. Report of Messrs Schröder and Lorent (Ibid. band iv. p. 486). In this Report is a good technical and financial account.

[||] Since this was written, Ballot (Medical Times and Gazette, 15th Feb. 1873) has spoken more favourably of it, and considers it to have been a decided success in Amsterdam and Leyden. Gori, on the other hand (Med. Times and Gazette, 8th March 1873), has replied to Ballot, denies that this is the case, and declares that in Amsterdam all with one consent say, "It is impracticable." Ballot adheres, however, to his statement.

I saw the system at work in Leyden in Sept. 1876, when much of its results and details was explained to me by the late Professor Boogaard. It seemed very effectual, and there was a total absence of odour, although I was present in some of the closets at the moment that the contents were sucked away by the apparatus. In Leyden the material is sold in barrels in the liquid form, but at Dordrecht, where the newest and most complete works are, it is made into poudrette, which is said to pay. In this country, Mr Adam Scott has done his best to bring it to public notice (see his papers in the Builder, Sanitary Record, Public Health, &c.) He considers that it has been shown by five years' experience in Holland, that the pneumatic system, by removing excrement without any possible pollution of air, soil, or water, has banished typhoid and diphtheria, as well as cholera and any diseases that are conveyed by the discharge from the intestines. The Committee on Town Sewage (Mr Rawlinson and Mr C. S. Roade) speak most disparagingly of it, more so, indeed, than seems warranted by all the evidence. On the other hand, the patent for Austria and Hungary has been purchased by the Vienna Joint-stock Agricultural Society, who consider it a success, both hygienically and financially. [F. de C.]

## COMPARISON OF THE DIFFERENT METHODS.

Much controversy has arisen on this point, though it does not appear that the question of the best mode of removing excreta is really a very difficult one. It is simply one which cannot be always answered in the same way.

It will probably be agreed by all that no large town can exist without sewers to carry off the foul house water, some urine and trade products, and that this sewer water must be purified before discharge into streams. The only question is, whether fæcal excreta should also pass into the sewers.

It will also be, no doubt, admitted that no argument ought to be drawn against sewers from imperfection in their construction. The advocate of water removal of solid excreta can fairly claim that his argument pre-supposes that the sewers are laid with all the precision and precaution of modern science; that the houses are thoroughly secured from reflux of sewer air; that the water-closets or water-troughs are properly used; and that the other conditions of sufficient water supply and power of disposal of the sewer water are also present. If those conditions are fulfilled, what reason is there for keeping out of the sewer water (which must, under any circumstance of urban life, be foul), the solid excreta, which, after all, cannot add very greatly to its impurity, and do add something to its agricultural value?

That it is not the solid excreta alone which cause the difficulty of the disposal of sewer water is seen from the case of Birmingham. That city is sewered; it contains nearly 350,000 inhabitants, and is in the greatest difficulty how to dispose of its sewer water; yet the solid excreta of only 20,000 persons pass into the sewers, while the solid excreta of 325,000 persons are received into middens.* The problem of disposal is as serious for Birmingham as if all the excreta passed in.

The great difficulty, in fact, consists not so much in the entrance of the solid excreta into sewers, as in the immense quantity of water which has to be disposed of in the case of very large inland towns with water-closets. If water-closets are not used, the amount of water supplied to towns, and that of sewer water, are considerably lessened.

Looking to all the conditions of the problem, it appears to me that it is impossible for all towns to have the same plan, and the circumstances of each town or village must be considered in determining the best method for the removal of excreta. London is particularly well adapted for water sewerage, on account of the conformation of the ground north of the Thames, of the number of streams (which have all been converted into sewers), and of the comparative facility of getting rid of its sewer water. The same may be said of Liverpool and many other towns. In Birmingham, on the other hand, the inland position, the price of land, and the comparative difficulty of getting water, seem to render other plans more desirable. If it had been possible, years ago, to act with our present knowledge, and to devise a scheme for Birmingham, it would have been best, I believe, to have taken the rainfall into the Rea; to have had the sewers merely for house and trade water (which would have given a manageable amount for filtration through land); and to have introduced the charcoal or some similar deodorising dry plan for the solid excreta, and for a part of the urine, with short periods of removal.

In many towns where land is more available, the immediate application to land, either by filtration or irrigation, may be evidently indicated by the conditions of the case, while in others precipitation may have to be resorted to before application to land. It does not appear that precipitation should in all cases precede irrigation or filtration, though mechanical arrest of the large suspended matters is necessary. There may be some towns, again, in which the impossibility of getting water or land may necessitate the employment of dry removal; and this is especially the case with small towns and villages, where the expense of good sewers and of a good supply of water is so great as to render it impossible to adopt removal by water. It may, indeed, be said that, in small towns in agricultural districts, the dry removal, if properly carried out, will be the best both for the inhabitants and for the land.

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* Report of the Birmingham Sewage Inquiry Committee (1871), Summary, p. 11. It should, however, be added that two-thirds of the middens drain into the sewers, *i.e.*, allow urine and some diffluent fæcal matter to pass in. In 1875, 128,512 tons of midden refuse were removed and sent to country depôts, to be afterwards disposed of to farmers.

The view here taken that no single system can meet all cases, and that the circumstances of every locality must guide the decision, is not a compromise between opposing plans, but is simply the conclusion which seems to me forced on us by the facts of the case. It does not invalidate the conclusion already come to, that where circumstances are favourable for its efficient execution, the water sewage plan (with or without interception of rainfall) is the best for large communities.

## SECTION III.

## DEODORISATION OF SEWAGE.

Under the headings of "Precipitation of Sewage" and "Dry Removal," the chief deodorisers have been noticed, but it may be convenient to give a recapitulation.

### Sub-Section I.

A very great number of substances have been added to sewage for the purpose of preventing decomposition and retaining the ammoniacal compounds.

1. *Charcoal*—which soon, however, gets clogged and loses its power—it is not nearly so useful when used in this way as in the purification of air. Sillar's preparation (the A, B, C deodorant) is a mixture of animal charcoal, blood, clay, and alum refuse. Messrs Weare & Co's is also a charcoal process.

2. *Dry earth*, especially, as already noticed, marly and clayey soils; the effect is similar to charcoal, but it is not so soon clogged. Dr Bird's preparation is ferruginous clay moistened with sulphuric acid, and then dried and pulverised. It is said to have a good effect.

3. *Quicklime* is sprinkled over the solid excreta, or quicklime and water added to sewer water, in proportion already given, till a deposit occurs, leaving a clear fluid above. This is chiefly caused by the lime forming insoluble salts, by union with carbonic and phosphoric acids, and mechanically carrying down the suspended matters. The sulphuretted hydrogen forms calcium sulphide, which remains in the supernatant fluid. The ammonia is set free. The potash salts remain in the liquid. Five-sixths of the phosphoric acid are in the precipitate. No organic matter is precipitated except mechanically. The solid deposit has little value as manure. The lime delays, but does not prevent the subsequent decomposition of the animal and vegetable matters, and as the calcium sulphide easily decomposes, sulphuretted hydrogen is very liable to be again set free from the clear fluid.

The process, though simple and cheap, is by no means perfect. The addition of charcoal to the lime does not materially modify the result.

From 15 to 16 grains of quicklime are enough for 1 gallon of sewage, or 20 cwt. per million gallons. At Leicester 580 tons of quicklime were used per annum for 4,700,000 tons of sewage. The process has now been discontinued there, but is still partially employed at Birmingham and elsewhere.

Hanson's process consists in the use of slaked lime and black ash refuse, or the soda and tank waste from the alkali works, mixed with sulphuric acid.

4. Cheap salts of *alumina*, and then lime, or alum sludge, lime, and waste animal charcoal (Manning), or zinc and charcoal (Stothert's process), alum, blood, and bone black (Sillar's process), chloride of aluminium (chlor-alum).

The alumina precipitated by the lime forms a very bulky precipitate, well suited to the entanglement of suspended matters. The clearance of the sewage is more perfect than with lime alone, but otherwise the process and the objections are the same, and the cost is greater. The whole of the phosphoric acid is precipitated as phosphate of alumina. To a gallon of sewage water there should be added 73½ grains of sulphate of alumina, 3½ grains of sulphate of zinc, 73½ grains of charcoal, 16¾ grains of quicklime.

Chlor-alum is a weak solution of chloride of aluminium; it is not a very powerful deodoriser, and must be used in large quantity, but its cheapness and want of poisonous properties* are recommendations, and when in sufficient amount it is effectual. It is efficacious against ammonia but not against sulphuretted hydrogen: it acts moderately against fæcal odour.

5. *Superphosphate of magnesia and lime water* (Blyth's patent). The idea was to add a substance which, in addition to deodorising, might be useful as a manure, and it was thought that a double phosphate of magnesia and ammonia would be thrown down; but this salt is sufficiently soluble in water, especially when the water contains chloride of sodium, to render this expectation incorrect. This method has been practically found to be useless, and to be more costly than any other plan.

6. *F. Hille*,† whose process is in use at Wimbledon, and is likely to be introduced in the town of Aldershot and elsewhere, uses a mixture of lime, tar, and salts of magnesium for defæcation and deodorising the sewage. The effluent water is then passed through artificial filters, or used for irrigation purposes. This plan has been well spoken of by Captain Flower‡ and others, and it appears to be moderate in cost compared with most other processes.

7. *Iron Perchloride.*—When this salt is added to sewage, a precipitate of ferric oxide is caused by the ammonium carbonate (which forms so rapidly in sewage), and carries with it all the suspended matters of the sewage. A clear fluid remains above. The sulphuretted hydrogen falls in the precipitate as iron sulphide. As the sulphide of iron tends to form ferric oxide, sulphur being let free, it has been conjectured by Hofmann that an oxidising effect from the oxide may follow the first action.

Both precipitate and supernatant liquid are free from odour.

This substance has been tried at Croydon and Coventry. From 14 to 29 grains per gallon of sewage are necessary for London sewage; for Croydon sewage from 5 to 15 grains were necessary. One gallon of liquid perchloride was sufficient for 15,000 gallons of sewage (Hofmann and Frankland).

The perchlorides of iron can be manufactured by dissolving in hydrochloric acid peroxide of iron, the different iron ores, refuse oxide of iron from sulphuric acid works, iron rust in foundries, &c. Another plan is to take equivalent proportions of common salt, sulphuric acid, iron rust, and water, so that chlorine, when disengaged, shall combine with the iron. A hard, yellowish, not very deliquescent substance, containing 26 per cent. of perchloride of iron, is formed, which can be transported to any distance. The price, if made in this way, is £2, 7s. per ton (cost of labour not included) in England.

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* In some samples I have found a considerable amount of lead. [F. de C.]

† System—F. Hille, Sewage Disinfecting and Filtration process, 2d edition, 1876.

‡ Sewage Treatment, more especially as affecting the pollution of the River Lee, a paper contributed to the Sewage Conference held by appointment of the Council of the Society of Arts, in May 1876, by Captain L. Flower, Sanitary Engineer, Lee Conservancy Board, &c.

The perchloride acts both on sulphuretted hydrogen and on sulphides, in both cases setting free sulphur. In sewage its ordinary action is on sulphide of ammonium.

Objections have been made to the perchloride, as it contains arsenic ; but the amount of this is small, and as it falls with the deposit it is never likely to be dangerous.

8. *Lueder and Leidloff's powder* consists (according to Leuchtenberg's analysis) of ferric sulphate, 36 per cent. ; ferrous sulphate, 16 ; free sulphuric acid, 4 ; calcium sulphate and other substances, 44. It has been highly commended, but, from experiments made at Netley, it does not seem very powerful.

9. *Lead Nitrate, or Ledoyen's Fluid,* is made by dissolving 1 ℔ of litharge in about 7 ounces of strong nitric acid and 2 gallons of water ; a little of the water is mixed with the litharge ; the acid is gradually added, and then the rest of the water. This quantity will deodorise a moderate-sized cesspool. It acts rapidly on sulphuretted hydrogen, and can be depended upon for this purpose.

10. *Zinc Chloride.*—Burnett's fluid contains 25 grains to every fluid drachm ; 1 pint is added to a gallon of water (1 to 8). It is usually said to decompose sulphuretted hydrogen until the solution becomes acid, when its action ceases ; but Hofmann finds that it does not act on free sulphuretted hydrogen, but on ammonium sulphide, forming zinc sulphide and ammonium chloride. It destroys ammoniacal compounds and organic matter. The sulphates of zinc and copper decompose free sulphuretted hydrogen, with formation of metallic sulphide and water.

Burnett's fluid delays decomposition in sewage for some time, and prevents the acidity of urine ; but a very peculiar odour is given out, showing that some change is going on. A good effect is produced on sulphuretted hydrogen by a mixture of zinc and ferrous sulphates (Larnaudès' mixture) which also lessens for the time the peculiar sewage smell.

11. *Zinc Sulphate.*—This forms part of the Universal Disinfecting Powder[*] (Langston-Jones' patent), along with Cooper's salts, viz., calcium and sodium chloride. This powder has the advantage of being inodorous, but it is not a strong deodorant. It, however, gets rid of fæcal odour to some extent, and is efficacious against $H_2S$.

12. *Potassium permanganate* prevents putrefaction for a short time, and removes the odour from putrefying sewage, but it requires to be used in large quantity. It has been proposed to use it and ferrous sulphate, first to oxidise and then to restrain alkalinity ; the way of doing this is to add the permanganate to the sewage first, and let it oxidise as far as it can, and then to add the ferrous sulphate, so as to remove the chance of action on the permanganate by the sulphate. But this plan has not succeeded in my hands. Although the large quantity of the permanganate which must be used makes it a bad sewage

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[*] Analysis (de Chaumont)—

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|---|---|
| Water | 7·40 |
| Calcium and Sodium Chlorides | 73·20 |
| Zinc Sulphate | 14·26 |
| Insoluble | 5·20 |
| Total | 100·06 |

To later samples some borate of lime was added. Probably the addition of ferrous sulphate might improve it.

deodorant, it has certainly a considerable action on fermenting liquids; and it might be useful to try its effect with cholera dejections, either alone, or, as Kühne recommends, with ferric sulphate, which will not be acted on by the permanganate like the green vitriol. It has also been recommended to mix it with chloride of soda solution.

13. Peparations from *coal-tar; carbolic acid* (phenol or phenic acid, or phenyl-alcohol ($C_6H_6O$)); coal-tar creasote, and cresylic acid (cresol or cresyl-alcohol, ($C_7H_8O$)), in various admixtures.* These substances are all excellent sewage deodorants and arresters of putrefaction.

The last few years have seen an extraordinary development in the manufacture of these substances. Phenol or carbolic acid is now obtained in great purity, and is sold in crystals, and also in a liquid form. All the preparations may be conveniently classed under the three divisions of crystals, liquids, and powders.

(*a*) *Crystals.*—Carbolic acid, more or less pure, is the only substance under this head; it is so slightly soluble in water that it is not so useful as a deodorant as the impurer kind. Carbolic acid is slightly soluble in water in the proportion of about 5 per cent. When mixed with sewage it acts slowly and not so perfectly as the impurer kinds. When exposed to the air it liquefies, and is slowly given out into the air, and is then supposed to be useful as an air purifier.

(*b*) *Liquids.*—Carbolic acid, more or less impure, dissolved in water, simply, or with a little alcohol and cresylic acid (cresol), forms the liquid carbolic acids. In the market they are found almost colourless, or highly coloured. The various liquids contain from 10 to 90 per cent. of phenol. Cresol, though crystalline and colourless when pure, is usually found in the market as a dark liquid. Some of it, no doubt, exists in most samples of carbolic acid. Owing probably to the way they mix at once with the sewage, the liquid acids are more deodorant than the crystallised acid, and restrain putrefaction for a long time. Carbolic acid, however, does not act on sulphuretted hydrogen, though it will restrain the processes which produce it.

Samples of so-called carbolic acid are sold, which are only impure tar-oils, and almost destitute of deodorising power. Sometimes a nauseous sulphur compound is also present.

Mr Crookes† gives the following rules in order to determine the presence ot the tar oils:—

"Commercial carbolic acid is soluble in from 20 to 70 parts of water, or in twice its bulk of a solution of caustic soda, while oil of tar is nearly insoluble, but if the amount of carbolic acid be increased, some remains undissolved.

"To apply the tests—1. Put a teaspoonful of the carbolic acid in a bottle, pour on it half a pint of warm water, and shake the bottle at intervals for half an hour, when the amount of oily residue will show the impurity; or dissolve one part of caustic soda in 10 parts of warm water, and shake it up with 5 parts of the carbolic acid. As before, the residue will show the amount of impurity.

"These tests will show whether tar oils have been used as adulterants, but to ascertain whether the liquid consists of a mere solution of carbolic acid in water or alkali, or whether it contains sulpho-carbolic or sulpho-cresylic acids, another test must be used based on the solubility of these, and the insolubility of carbolic acid in a small quantity of water. In this case proceed as follows :—2. Put a wine-glassful of the liquid to be tested in a bottle, and pour on it half a pint of warm water. If the greater part dissolves, it is an adulterated article. Test the liquid in the bottle with litmus paper; if strongly acid, it will show the probable presence of sulpho-acids; whilst if alkaline, it will show that caustic soda has been probably used as a solvent."

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* It is perhaps unfortunate that phenol and cresol, which are rather alcohols than acids, should have been termed carbolic and cresylic acids. If the terms phenol and cresol could be used instead it would be better. But I have thought it better not to abandon at present terms which have got into general use.

† Third Report—Cattle Plague Commission. Carbolic acid can be distinguished from creosot by its solubility in glycerine (Morson).

If the quantity of carbolic acid has to be estimated from a liquid, it must be distilled at a given temperature. Carbolic acid boils at 184° C. (= 363° Fahr.), cresol at 203° C. (= 397°·4 Fahr.)

In using the liquid acid, 1 part is mixed with 50 or 100 of water, according to the strength of the acid, and thrown down drains or into cesspools, or sprinkled with a watering-can over dung-heaps.

(c) *Powders.*—The two principal carbolic acid powders are M'Dougall's and Calvert's, but there are several others in the market known under various names.

M'Dougall's and Calvert's powders are widely different in composition.

The former is strongly alkaline from lime, and makes the sewage alkaline. It consists of about 33 per cent. of carbolate of lime and 59 per cent. of sulphite of magnesia, the rest being water.

Calvert's powder is carbolic acid, about 20 to 30 per cent., mixed with alumina from alum works, and some silica.

The quantity of these preparations which must be used depends on the degree and duration of deodorisation wished for. For the daily solid excreta (4 ounces) of an adult at least from 30 to 70 grains of the crystallised acid, 60 drops of the strong liquid (90 per cent. of acid), or ½ ounce of the dilute carbolic acid, sold at 1s. per pint, are necessary, if the sewage is to be kept in an unaltered state for 10 to 20 days, but a smaller amount is sufficient for 2 or 3 days.[*] Dr Sansom, who does not rate the effect of carbolic acid so highly as a deodorant, also finds that much larger quantities must be used than is usually stated (*op. cit.* p. 203). Half an ounce of either Calvert's or M'Dougall's powder for 4 ounces of sewage has a preservative effect for 18 to 20 days; ¼ ounce or less is effectual for 3 or 4 days, but if the stools contain urine much more is necessary.[†]

Smaller quantities can, however, be used, if diminution, but not entire removal of smell and putrefaction is desired. Quicklime 5 parts, and carbolic acid 1 part, make a good deodorising fluid. If hydrochloric acid is added, and then water, the lime is deposited, and the carbolic acid floats on the surface, and its amount can be determined.

14. *The Süvern Deodorant.*—The water flowing from sugar factories has long been a source of annoyance and ill-health; it contains quantities of vegetable organisms (*Oscillaria alba* or *Beggiatoa*), which act like ferments, and rapidly decompose the sulphates in the water, and liberate sulphuretted hydrogen. Herr Süvern, to remedy this, proposed a preparation of coal-tar thus prepared.[‡] A bushel and a half of good quicklime are put in a cask and slaked; it is well stirred, and 10 ℔ of coal-tar are thoroughly mixed with it, so that the coal-tar may be thoroughly divided. Fifteen pounds of magnesium

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[*] See my experiments in the Army Medical Department Report, vol. viii. p. 318.

[†] Dr John Day (of Geelong) published a paper in the *Australian Medical Journal* (June 1874), on the comparative value as disinfectants of carbolic acid and mineral oils, such as gasolene and kerosene. He prefers gasolene, and finds it may be used for papered walls, furniture, clothing, and flooring. It must be used with caution near lights, as it is very inflammable. Dr Day attributes its action to its strong oxidising properties; paper brushed over with it gave the reaction of peroxide of hydrogen after more than a year.

[‡] Trautman, Die Zersetzungsgase, 1869, p. 35.

chloride dissolved in hot water are then thoroughly mixed with the mass, and then additional hot water is added, sufficient to make a mass of just sufficient liquidity to drop slowly from a stick inserted in it and then pulled out. The magnesium chloride forms deliquescent calcium chloride, magnesia being liberated, and it is found that this prevents the caking of the deodorant and the adherence to pipes. This deodorant has come into considerable use for cesspools, drains, &c. The Müller-Schurr deodoriser has been already noticed.

15. Dr F. T. Bond (of Gloucester) has introduced a new deodorant in the form of powder and liquid, consisting essentially of metallic salts, alum, and *terebene* (a hydrocarbon derived from turpentine by treatment with sulphuric acid.) Terebene has a pleasant odour, and so far is superior to carbolic acid: its deodorising powers are very considerable. The preparations in the form of powder are various, the chief being *Ferralum* and *Cupralum*, the latter being most frequently employed. It consists of copper sulphate, alum, a little potassium bichromate, and terebene. It is a very powerful deodorant, counteracting ammonia and sulphuretted hydrogen, and at least masking fæcal odour as much as carbolic acid.*

16. The remarkable power shown by *Salicylic acid* in arresting fermentation, and its value in the antiseptic treatment of wounds, would seem to indicate it as a good agent, but it is at present too expensive for use on a large scale.

*General Conclusion.*—It must be remembered that deodorisation is only possible within certain limits, and that in a number of cases only partial results can be obtained, unless very large quantities of the deodorant are used.† The most effectual appear to be the terebene preparations, especially the cupralum, and carbolic acid and its preparations. Of these the cupralum has the advantage of destroying sulphuretted hydrogen and neutralising ammonia, which are only masked by the others. Chloride of lime and chloride of soda are also powerful, but have themselves a sickly odour, very disagreeable to many persons. The Süvern deodorant is probably the next best, and after that the ferric chloride ($FeCl_3$ or feCl).

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* The substance advertised as "Sanitas," is a hydrocarbon derived from the resin of the *Eucalyptus Globulus* (Blue Gum Tree).

† In experimenting with the very offensive infusion of linseed, it was found almost impossible to get rid of odour without using very large quantities of the deodorants. [F. de C.]

# CHAPTER XI.

# WARMING OF HOUSES.

The heat of the human body can be preserved in two ways :—

1. The heat generated in the body, which is continually radiating and being carried away by moving air, can be retained and economised by clothes. If the food be sufficient, and the skin can thus be kept warm, there is no doubt that the body can develop and retain its vigour with little external warmth. In fact, provided the degree of external cold be not too great (when, however, it may act in part by rendering the procuring of food difficult and precarious), it would seem that cold does not imply deficiency of bodily health, for some of the most vigorous races inhabit the cold countries. In temperate climates there is also a general impression (and such general impressions are often right) that for healthy adults external cold is invigorating, provided food be sufficient, and if the internal warmth of the body is retained by clothing.

2. External heat can be applied to the body either by the heat of the sun (the great fountain of all physical force, and vivifier of life), or by artificial means, and in all cold countries artificial warming of habitations is used.

The points to determine in respect of habitations are—

*1st*, What degree of artificial warmth should be given ?

*2d*, What are the different kinds of warmth, and how are they to be given ?

## SECTION I.

### DEGREE OF WARMTH.

*For Healthy Persons.*—There appears no doubt that both infants and old persons require much artificial warmth, in addition even to abundant clothes and food. The lowering of the external temperature, especially when rapid, acts very depressingly on the very young and old ; and when we remember the extraordinary vivifying effect of warmth, we cannot be surprised at this.

For adult men of the soldier's age, who are properly fed and clothed, it is probable that the degree of temperature of the house is not very material, and that it is chiefly to be regulated by what is comfortable. Any temperature over 48° up to 60° is felt as comfortable, though this is dependent in part on the temperature of the external air. It seems certain that for healthy, well-clothed, and well-fed men we need not give ourselves any great concern about the precise degree of warmth.

For children and aged persons we are not, I believe, prepared to fix any exact temperature ; for new-born children a temperature of 65° to 70°, or even more, may be necessary, and old people bear with benefit a still higher warmth.*

*For Sick Persons.*—The degree of temperature for sick persons is a matter of great importance, which requires more investigation than it has received. There seems a sort of general rule that the air of a sick-room or hospital should be about 60° Fahr., and in most Continental hospitals, warmed artificially, this is the contract temperature; but the propriety of this may be questioned.[*]

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* It is singular, however, that in some old people the temperature of the body is higher than normal (John Davy). Is there, then, a difference in the amount of external heat required in different persons ?

There are many diseases greatly benefited by a low temperature, especially all those with preternatural heat. It applies, I believe, almost without exception (scarlet fever ?) to the febrile cases in the acute stage, that it is desirable to have the temperature of the air as low as 50°, or even 45° or 40°. Cold air moving over the body is a cooling agent of great power, second only, if second, to cold affusion, nor is there danger of bad results if the movement is not too great. The Austrian experiments on tent hospitals[†] show conclusively that even considerable cold is well borne. Even in the acute lung affections this is the case. Pneumonia cases do best in cold wards, provided there is no great current of air over them. Many cases of phthisis bear cool air, and even transitions of temperature, well, provided there be no great movement of air. On the other hand, it has appeared to me that chronic heart diseases with lung congestion, emphysema of the lungs, and diseases of the same class, require a warm air, and perhaps a moist one. With respect to the inflammatory affections of the throat, larynx, and trachea, I have no decided evidence of my own, and have been able to find nothing decisive in authors on this point; but the spasmodic affections of both larynx and bronchial tubes seem benefited by warmth.

In the convalescence, also, from acute disease, cold is very badly borne; no doubt, the body, after the previous rapid metamorphosis, is in a state very susceptible to cold, and, like the body of the infant, resists external influences badly. Convalescents from fever must therefore be always kept warm. This is probably the reason why it is found inadvisable to transfer febrile patients treated in a permanent hospital to convalescent tents, although patients treated from the first in tents have a good convalescence in them, as if there were something in habit.

## SECTION II.

## DIFFERENT KINDS OF WARMTH.

Heat is communicated by radiation, conduction, and convection. The latter term is applied to the conveyance from one place to another of heat by means of masses of air, while conduction is the passage of heat from one particle to another—a very slow process. Practically, conduction and convection may be both considered under the head of convection.

Radiant heat has been considered by most writers the best means of warming; it heats the body without heating the air,[‡] and of course there is no possibility of impurity being added to the air.

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[*] It is owing to this rule that in French hospitals, artificially ventilated and warmed by hot air, the amount of air is lessened and its temperature heightened in order to keep up the contract temperature of 15° C. (=59° F.) The air is often then close and disagreeable. A safe general rule is never to sacrifice fresh air to temperature, except in the most extreme cases. Of course, cold currents of air are to be avoided if possible, but it is safer, as a rule, to let the general temperature go down, rather than diminish the change of air. In most cases it can be compensated for by additional covering.

[†] See Report on Hygiene in the Army Medical Report for 1862, by the author.—*Blue Book*, 1864. The Prussians have also lately made great use of tents in the summer.

[‡] My friend, Dr Sankey, has made experiments which show that the temperature of the air of a room heated by radiant heat is really lower than the indicated temperature of the air, because the bulb is warmed by radiation. When this is prevented by enclosing the bulb in a bright tin case the thermometer falls.

The disadvantages of radiant heat are its cost, and its feebleness at any distance. The cost can be lessened by proper arrangement, but the loss of heat by distance is irremediable. The effect lessens as the square of the distance—*i.e.*, if, at 1 foot distance from the fire, the warming effect is said to be equal to 1, at 4 feet distance it will be sixteen times less. A long room, therefore, can never be warmed properly by radiation.

It has been attempted to calculate the amount of air warmed by a certain space of incandescent fire, and 1 square inch has been supposed sufficient to warm 8·4 cubic feet of air. But much depends on the walls, and whether the rays fall on them and warm them, and the air passing over them.

Radiating grates should be so disposed as that every ray is throw out into the room. The rules indicated by Desaguliers were applied by Rumford. Count Rumford made the width of the back of the grate one-third the width of the hearth recess; the sides then sloped out to the front of the recess; the depth of the grate from before backwards was made equal to the width of the back. The sides and back were to be made of non-conducting material; the chimney throat was contracted so as to lessen the draught, and insure more complete combustion. The grate was brought as far forward as possible, but still under the throat.

The open chimney, which is a necessity of the use of radiant grates, is so great an advantage that this is *per se* a strong argument for the use of this kind of warming, but, in addition, there can be little doubt that radiant heat is really the healthiest.

Still the immense loss of heat in our common English fire-places must lead to a modification, and radiant heat must be supplemented by

### *Convection and Conduction.*

The air is heated in this case by passing over hot stones, earthenware, iron or copper plates, hot water, steam, or gas pipes. The air in the room is thus heated, or the air taken from outside is warmed, and is then allowed to pass into the room, if possible at or near the floor, so that it may properly mingle with the air already there. The heat of the warming surface should not be great, probably not more than 120° to 140° Fahr.; there should be a large surface feebly heated. The air also should not be heated above 75° or 80° Fahr., and a large body of air gently heated should be preferred to a smaller body heated to a greater extent, as more likely to mix thoroughly with the air of the room.

It does not matter what the kind of surface may be, provided it is not too hot. If it is, the air acquires a peculiar smell, and is said to be burnt; this has been conjectured to be from the charring of the organic matter. Some have supposed the smell to be caused by the effect of the hot air on the mucous membrane of the nose, but it is not perceived in air heated by the sun. Such air is also relatively very dry, and absorbs water eagerly from all substances which can yield it.

If the air is less heated (not more than 75°) it has no smell, and the relative humidity is not lessened to an appreciable extent. Haller's experiments, carried on over six years with the Meissner stove common in Germany, show that there the relative moisture is not lessened with moderate warming,[*] and I have found the same result with the Galton stoves. On the other hand, when the plates are too hot, the air may be really too much dried, and Dr Sankey informs me that while he never found the difference between the dry and wet bulbs in a room warmed by radiant heat to be more than 8° Fahr., he has noticed in rooms warmed by hot air a difference of 15° to 17° Fahr., which implies a relative humidity, if the temperature be 60°, of only 34 per cent. of saturation, which is much too dry for health. In this case the air is always unpleasant, and must be moistened by passing over water before it enters the room, if possible; some heat is thus lost, but not much. Of the various means of heating, water is the best, as it is more under control, and the heat can be carried everywhere. Steam is equally good, if waste steam can be utilised, but if not, it is more expensive. Hot-water pipes are of two kinds: pipes in which the water is not heated above 200° Fahr., and which, therefore, are not subjected to great pressure; and pipes in which the water is heated to 300° or 350° Fahr., and which are therefore subjected to great pressure. These pipes (Perkin's patent) are of small internal calibre (about ½ inch), with thick walls made of two pieces of welded iron; the ends of the pipes are joined by an ingeniously contrived screw. In the low-pressure pipes there is a boiler from which the water circulates through the pipes and returns again, outlets being provided at the highest points for the exit of the air. In Perkin's system there is no boiler; one portion of the tube passes through the fire.

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[*] Die Lüftung und Erwärmung der Kinderstube und des Krankenzimmers, von D. C. Haller, 1860, pp. 29–38.

Mr Hood states that 5 feet of a 4-inch pipe will warm 1000 cubic feet in a public room to 55°. In dwelling-houses for every 1000 cubic feet 12 feet of 4-inch pipe should be given, and will warm to 65°. In shops, 10 feet, and in workrooms 6 feet, per 1000 cubic feet are sufficient. If Perkins' pipes are used, as the heating power is greater, a less amount does, probably about two-thirds, or a little more.

Steam piping is now also much used, and in some cases is more convenient even than water. The Houses of Parliament are warmed by steam pipes in a chamber under the floor; the radiating surface of the pipes is increased by soldering on to them at intervals a number of zinc or (preferably) small copper plates. If it is wished to lessen the amount of heat, the pipes, where provided with thin plates, are simply covered with a woollen cloth.

The easy storing up and conveyance of heat to any part of the room or house by means of water pipes, the moderate temperature, and the facility of admission of external air at any point by passing the fresh air over coils, or water leaves, make it certain that the plan of warming by hot water will be greatly used in time to come, although the open fire-place may be retained for comfort.

Mr George has devised a gas stove (called the Calorigen), which appears to be a decided improvement on the common gas stove. Gas is burnt in a small iron box, and the products of combustion are carried to the open air by a tube. Another coiled tube runs up through the box; this communicates below with the outer air, and above opens into the rooms. As the fresh air passes through this tube it is warmed by the heat of the gas stove. Mr Eassie speaks very well of this stove, which he has put up in several places. He says he has known one to be persistently capable of registering fifteen degrees above the external temperature during a very severe winter, and that, too, in a room of over 1700 cubic feet, with the roof and three sides constructed of glass.* A coal calorigen is also made which seems to answer well.

A plan which was proposed 130 years ago by Desaguliers is now coming into general use, viz., to have an air chamber round the back and sides of a radiating grate, and to pass the external air through it into the room. Thus a great economy of heat, and a considerable quantity of gently-warmed air, passes into the room. In Captain Galton's grate, and in the plan proposed by

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* *Sanitary Arrangements for Dwellings*, 1874, p. 140.

Mr Chadwick for cottages, the lower part of the chimney is also made use of. The advantages of these grates are that they combine a good amount of cheerful open fire, radiant heat, and chimney ventilation, with supplementary warming by hot air, so that more value is obtained from the fuel, and larger spaces can be more effectually warmed. A great number of patents have been taken out for grates of this kind. The air-chamber should not be too small, or the air is unduly heated; the heated surface should be very large; fire-clay sometimes gives a peculiar odour to the air, which iron does not do if the surface of iron be very large and disposed in gills; a combination also of iron and fire-clay is said to be good, and to give no odour. The conduit leading to the air-chamber should be short, and both it and the chamber should be able to be opened and cleaned, as much dust gets in. The room opening of the air-chamber should be so far up that the hot air may not be at once breathed, and there should be no chance of its being at once drawn up the chimney. The action of all stoves of the kind is liable to considerable variation from the action of the wind; and sometimes the current is even reversed, and hot air is driven out.

Attention has been lately directed both in France and America to the fact of the comparative ease with which gases pass through red hot cast-iron. Mr Graham has shown that iron heated to redness will absorb 4·15 times its volume of carbonic oxide, and the experiments by MM. Deville and Troost, made at the request of General Morin, prove that in a cast-iron stove heated with common coal there passed through the metal in 92 hours 589 C.C. of carbonic oxide,* or from ·0141 to ·132 per cent. of the air which was slowly passed over the hot surface. In America, Dr Derby† has directed particular attention to this point, and has adduced very strong reasons for believing that the decidedly injurious effects produced by some of the plans of warming houses, especially by air passing over a cast-iron furnace heated with anthracite, is due to an admixture of carbonic oxide. Professor Coulier of the Val de Grâce,‡ has contended that the amount of carbonic oxide passing through in the experiments of Deville and Troost is really so small, that if mixed with the air of a room which is fairly ventilated, it would be quite innocuous; and he believes (from direct experiment) that the headache and oppressive feeling produced by these iron stoves are really owing, as was formerly believed, to the relative dryness of the air. But evidence is adverse to this now. The gas passes with much greater difficulty through wrought-iron, or through stoves lined with fire-clay.§

A great number of grates and stoves have been proposed, which it is impossible here to notice. In Germany many excellent stoves are now used, which not only economise fuel, but warm the outside air, which is admitted round or under them.‖ The medical officer's advice will be sought, first, as to the kind; and second, as to the amount of heat. He will find no difficulty in coming to the conclusion that in most cases both methods (radiation and convection) should be employed; the air warmed by plates or coils of water pipes being taken fresh from the external air and thereby conducing to ventilation. He will be also called on to state the relative amount of radiant and convected heat, and to determine the heat of the plates, and of the air coming off them, and the degree of humidity of the air. The thermometer, and the dry and wet bulbs, will give him all the information he wants on these points.*

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* Comptes Rendus de l'Acad. Jan. 1868. These experiments were first undertaken in consequence of a statement by Dr Carret, that in the department of Haute-Savoie an epidemic occurred which affected persons only in the houses where iron stoves were, and not porcelain.

† Anthracite and Health, by G. Derby, M.D., Professor of Hygiene in Harvard University.

‡ Mem. de Med. Mil. Sept. 1868, p. 250.

§ Dr Bond has recommended a coating of silicate as a preventive against the passage of deleterious products through an iron stove.

‖ See a good account in Roth and Lex's work (op. cit. p. 365.)

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* Mr Chadwick has lately called attention to the old Roman plan of the Hypocaust, where the floor of the room is warmed by pipes, or by carrying smoke-flues under it, and he has contrived some ingenious plans to carry out the idea. There can be no doubt of the great comfort of this plan, although it appears to be expensive. Attention has been called, of late years, to heating on the *whole house* system, and there can be no doubt that this is an excellent plan, if properly carried out and carefully supervised. Drs Drysdale and Hayward in this country (Health and Comfort in House Building, London, 1872), and Dr Griscom of New York, have devised ingenious plans for the purpose. In older countries, such as Russia, the plan is in general use, but apparently with little or no regard to proper supply of fresh air, or carrying away of foul air.

# CHAPTER XII.

# EXERCISE.

A PERFECT state of health implies that every organ has its due share of exercise. If this is deficient, nutrition suffers, the organ lessens in size, and eventually more or less degenerates. If it be excessive, nutrition, at first apparently vigorous, becomes at last abnormal, and, in many cases, a degeneration occurs which is as complete as that which follows the disuse of an organ. Every organ has its special stimulus which excites its action, and if this stimulus is perfectly normal as to quality and quantity, perfect health is necessarily the result.

But the term exercise is usually employed in a narrower sense, and expresses merely the action of the voluntary muscles. This action, though not absolutely essential to the exercise of other organs, is yet highly important, and indeed, in the long run, is really necessary; the heart especially is evidently affected by the action of the voluntary muscles, and this may be said of all organs, with the exception perhaps of the brain. Not only the circulation of the blood, but its formation and its destruction, are profoundly influenced by the movement of the voluntary muscles. Without this muscular movement health must inevitably be lost, and it becomes therefore important to determine the effects of exercise, and the amount which should be taken.

## SECTION I.

### THE EFFECTS OF EXERCISE.

(*a*) *On the Lungs—Elimination of Carbon.*—The most important effect of muscular exercise is produced on the lungs. The pulmonary circulation is greatly hurried, and the quantity of air inspired, and of carbonic acid expired, is marvellously increased. Dr Edward Smith has carefully investigated the first point, and the following table shows his main results. Taking the lying position as unity, the quantity of air inspired was found to be as follows:—

| | | | |
|---|---|---|---|
| Lying position, | 1 | Walking and carrying 63 ℔, | 3·84 |
| Sitting, | 1·18 | „ „ 118 ℔, | 4·75 |
| Standing, | 1·33 | „ 4 miles per hour, | 5 |
| Singing, | 1·26 | „ 6 „ | 7 |
| Walking 1 mile per hour, | 1·9 | Riding and trotting, | 4·05 |
| „ 2 „ | 2·76 | Swimming, | 4·33 |
| „ 3 „ | 3·23 | Treadmill, | 5·5 |
| „ and carrying 34 ℔, | 3·5 | | |

The great increase of air inspired is more clearly seen when it is put in this way: under ordinary circumstances a man draws in 480 cubic inches per minute; if he walks four miles an hour he draws in (480 × 5 =) 2400 cubic inches; if 6 miles an hour (480 × 7 =) 3260 cubic inches. Simultaneously, the amount of carbonic acid in the expired air is increased (Scharling and many others).

The most reliable observations in this direction are those made by E. Smith, Hirn,[*] Speck,[†] and Pettenkofer and Voit.[‡] As there is no doubt that the peculiar means of investigation render the experiments of the last-named authors as accurate as possible in the present state of science, I give them briefly in the following table.[§]

*Absorption and Elimination in Rest and Exercise.*

| | Absorption of Oxygen in Grammes. | Elimination in Grammes of— | | |
|---|---|---|---|---|
| | | Carbonic Acid. | Water. | Urea. |
| Rest-day, . . . . . . | 708·9 | 911·5 | 828·0 | 37·2 |
| Work-day, . . . . . . | 954·5 | 1284·2 | 2042·1 | 57 |
| Excess on work-day (with exception of urea), . . . . . . | 246·6 | 372·7 | 1214·1 | –0·2 |

In other words, during the work-day, 3804 grains or 8·69 ounces of oxygen were absorbed in excess of the rest-day, and 5750 grains or 13 ounces in excess of carbonic acid were evolved. Expressing this as carbon, an excess of 1568 grains or 3·58 ounces were eliminated in the work-day. There was an excess of oxidation of carbon equal to 34·6 per cent., and it must be remembered that the so-called "work-day" included a period of rest; the work was done only during working hours, and was not excessive.

It will be observed from these experiments that a large amount of water was eliminated during exercise, while the urea was slightly lessened.

It seems certain that the great formation of carbonic acid takes place in the muscles;[||] it is rapidly carried off from them, and if it is not so, it would seem highly probable that their strong action becomes impossible. At any rate, if the pulmonary circulation and the elimination of carbonic acid are in any way impeded, the power of continuing the exertion rapidly lessens. The watery vapour exhaled from the lungs is also largely increased during exertion.

Muscular exercise is then clearly necessary for a sufficient elimination of carbon from the body, and it is plain that, in a state of prolonged rest, either the carboniferous food must be lessened or carbon will accumulate.

Excessive and badly arranged exertion may lead to conjestion of the lungs and even hæmoptysis. Deficient exercise, on the other hand, is one of the causes which produce those nutritional alterations in the lung which we class as tuberculous.

Certain rules flow from these facts. During exercise the action of the lungs must be perfectly free; not the least impediment must be offered to the freest play of the chest and the action of the respiratory muscles. The dress and accoutrements of the soldier should be planned in reference to this fact, as there is no man who is called on to make, at certain times, greater exertion. And yet, till a very recent date, the modern armies of Europe were dressed and accoutred in a fashion which took from the soldier, in a great degree, that power of exertion for which, and for which alone, he is selected and trained.

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[*] Ludwig's Phys. 2d edit. band i. p. 748.

[†] Archiv des Vereins für wiss. Heilk. band vi. pp. 285 and 289.

[‡] Zeitsch. für Biologie, bands ii. and iii., and Ranke's Phys. des Menschen, p. 551.

[§] The numbers given by Hirn and Speck are very accordant; they will be found quoted in the 2d edition of this work, if it is wished to refer to them.

[||] See the observations of Valentin and others, and especially the experiments of Sczelkow (Henle's Zeitschrift, 1862, band xvii. p. 106). The amount of $CO_2$ passing off from contracting muscles was indeed so great, and so much in excess of the O passing to them, that it was conjectured that carbonic acid must have been formed during contraction from substances rich in oxygen (such as formic acid), or that oxygen must have been obtained otherwise than from inspiration.

The action of the lungs should be watched when men are being trained for exertion; as soon as the respirations become laborious, and especially if there be sighing, the lungs are becoming too congested, and rest is necessary.

A second point is, that the great increase of carbon excreted demands an increase of carbon to be given in the food. There seems a general accordance, among physiologists, that this is best given in the form of fat, and not of starch, and this is confirmed by the instinctive appetite of a man taking exertion, and not restrained in the choice of food.

A third rule is, that as spirits lessen the excretion of pulmonary carbonic acid, they are hurtful during exercise; and it is perhaps for this reason, as well as from their deadening action on the nerves of volition, that those who take spirits are incapable of great exertion. This is now well understood by trainers, who allow no spirits, and but little wine or beer. It is a curious fact, stated by Artmann, that if men undergoing exertion take spirits, they take less fat. Possibly in reality they lessen the amount of exertion, and therefore require less fat. Water alone is the best fluid to train on.

A fourth rule is, that as the excretion of carbonic acid (and perhaps of pulmonary organic matter) is so much increased, a much larger amount of pure air is necessary; and in every covered building (as gymnasia, riding-schools, &c.) where exercise is taken, the ventilation must be carried to the greatest possible extent, so soon does the air become vitiated.

(*b*) *On the Heart and Vessels.*—The action of the heart rapidly increases in force and frequency, and the flow of blood through all parts of the body, including the heart itself, is augmented. The amount of increase is usually from ten to thirty beats, but occasionally much more. After exercise, the heart's action falls below its normal amount; and if the exercise has been exceedingly prolonged and severe, may fall as low as fifty or forty per minute, and become intermittent. During exertion, when the heart is not oppressed, its beats, though rapid and forcible, are regular and equable; but when it becomes embarrassed, the pulse becomes very quick, small, and then unequal, and even at last irregular. When men have gone through a good deal of exertion, and then are called upon to make a sudden effort, I have known the pulse become very small and quick (160–170), but still retain its equability. There seems no harm in this, but such exertion cannot be long continued.

The ascension of heights greatly tries a fatigued heart. The accommodation of the heart to great exertion is probably connected with the easy flow of blood through its own structure.

Excessive exercise leads to affection of the heart; rupture (in some few cases), palpitation, hypertrophy in a good many cases, and more rarely valvular disease. These may be avoided by careful training, and a due proportion of rest. Injuries to vessels may also result from too sudden or prolonged exertion. The sphygmographic observations of Dr Fraser* on the pulses of men after rowing, show how much the pressure is increased.

Deficient exercise leads to weakening of the heart's action, and probably to dilatation and fatty degeneration.

In commencing an unaccustomed exercise, the heart must be closely watched; excessive rapidity (120–140), inequality, and then irregularity, will point out that rest, and then more gradual exercise, is necessary, in order that the heart may be accustomed to the work.

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* Journal of Physiology, Nov. 1868.

(c) *On the Skin.*—The skin becomes red from turgescence of the vessels, and perspiration is increased; water, chloride of sodium, and acids (probably in part fatty), pass off in great abundance. It was formerly supposed that urea also passed off in this way, but this is not the case. No gaseous nitrogen is given off in healthy men from the skin.

The amount of fluid passing off is not certain, but is very great. Speck's experiments show that it is at least doubled under ordinary conditions. Pettenkofer and Voit's experiments show even a larger increase. The usual ratio of the urine to the lung and skin excreta is reversed. Instead of being 1 to 0·5 or 0·8, it becomes 1 to 1·7 or 2, or even 2·5. This evaporation reduces and regulates the heat of the body, which would otherwise soon become excessive; so that, as long ago pointed out by Dr John Davy, the body temperature rises little above the ordinary temperature. No amount of external cold seems to be able to hinder the passage of fluid, though it may partly check the rapidity of evaporation. If anything check evaporation, the body-heat increases, and soon languor comes on and exertion becomes difficult.

During exertion there is little danger of chill under almost any circumstances; but when exertion is over, there is then great danger, because the heat of the body rapidly declines, and falls below the natural amount, and yet evaporation from the skin, which still more reduces the heat, continues.

The rules to be drawn from these facts are—that the skin should be kept extremely clean; during the period of exertion it may be thinly clothed, but immediately afterwards, or in the intervals of exertion, it should be covered sufficiently well to prevent the least feeling of coolness of the surface. Flannel is best for this purpose.

(d) *On the Voluntary Muscles.*—The muscles grow, become harder, and respond more readily to volition. Their growth, however, has a limit; and a single muscle, or group of muscles, if exercised to too great an extent, will, after growing to a great size, commence to waste. But this seems not to be the case when all the muscles of the body are exercised, probably because no muscle can then be over-exercised. It seems to be a fact, however, that prolonged exertion, without sufficient rest, damages to a certain extent the nutrition of the muscles, and they become soft.

The rules to be drawn from these facts are, that all muscles, and not single groups, should be brought into play, and that periods of exercise must be alternated, especially in early training, with long intervals of rest.

(e) *On the Nervous System.*—The effect of exercise on the mind is not clear. It has been supposed that intellect is less active in men who take excessive exercise, owing to the greater expenditure of nervous force in that direction. But there is no doubt that great bodily is quite consistent with extreme mental activity; and, indeed, considering that perfect nutrition is not possible except with bodily activity, we should infer that sufficient exercise would be necessary for the perfect performance of mental work. Doubtless, exercise may be pushed to such an extreme as to leave no time for mental cultivation; and this is perhaps the explanation of the proverbial stupidity of the athletæ. Deficient exercise causes a heightened sensitiveness of the nervous system, a sort of morbid excitability, and a greater susceptibility to the action of external agencies.

(f) *On the Digestive System.*—The appetite largely increases with exercise, especially for meat and fat, but in a less degree, it would appear, for the carbohydrates. Digestion is more perfect, and absorption is more rapid. The circulation through the liver increases, and the abdominal circulation is carried on with more vigour. Food must be increased, especially nitrogenous substances, fats, and salts, and of these especially the phosphates and the chlorides.* The effects of exercise on digestion are greatly increased if it be taken in the free air, and it is then a most valuable remedy for some forms of dyspepsia. (James Blake, *Pacific Medical and Surgical Journal*, 1860.) Conversely, deficient exercise lessens both appetite and digestive power.

(*g*) *On the Generative Organs.*—It has been supposed that puberty is delayed by physical exertion, but perhaps the other circumstances have not been allowed full weight. Yet, it would appear that very strong exercise lessens sexual desire, possibly because nervous energy is turned in a special direction.

(*h*) *On the Kidneys.*—The water of the urine and the chloride of sodium often lessen in consequence of the increased passage from the skin. The urea is not much changed (see after). The uric acid increases after great exertion; so also apparently the pigment; the phosphoric acid is not augmented;† the sulphuric acid is moderately increased; the free carbonic acid of the urine is increased; the chlorides are lessened on account of the outflow by the skin; the exact amount of the bases has not been determined, but a greater excess of soda and potash is eliminated than of lime or magnesia; nothing certain is known as to hippuric acid, sugar, or other substances.‡

(*i*) *On the Bowels.*—The effect of exercise is to lessen the amount, partly, probably from lessened passage of water into the intestines. The nitrogen does not appear to be much altered.§

(*k*) *On the Elimination of Nitrogen.*—A great number of experiments have been made in the amount of nitrogen passing off by the kidneys during exercise.‖ The amount of urea has been usually determined, and the nitrogen has been calculated from this; Meissner has determined the amount of the creatin, and the creatinine;¶ while Fick, and Wislicenus have compared the total nitrogen (by soda lime in the manner of Voit) as well as the ureal nitrogen, and I have repeated their experiments.** The experiments have been usually carried on by determining the nitrogenous excretion in twenty-four hours with and without exercise; but in some, the period during which

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* It is yet uncertain what kind of diet should be allowed during long marches in the tropics. Dr Kirk has informed me that in South Africa (10° to 17° S.L.), during Dr Livingstone's second expedition, a large quantity (2℔) of animal food was found to be essential; this was preferred, though any quantity of millets and leguminosæ could have been procured. Fat was taken in large quantities. It was found, also, that boiled was better than roast meat, because the men could eat more of it. No bad effect whatever was traceable to the use of this great amount of meat, even in the intensest heat.

† I believe I can be certain of this from my own experiments.

‡ In the careful observations made by Dr Pavy on Weston the pedestrian (Lancet, Dec. 1876), the following changes were found; taking the amount excreted during rest as 1:—

| Constituents. | Rest. | Walking. |
|---|---|---|
| Urea | 1 | 1·743 |
| Uric acid | 1 | 1·287 |
| Chlorine | 1 | ·478 |
| Sulphuric acid | 1 | 1·520 |
| Phosphoric acid | 1 | 1·985 |
| Soda | 1 | ·822 |
| Potash | 1 | 1·424 |
| Lime | 1 | 1·559 |
| Magnesia | 1 | ·989 |

All the constituents thus appear to be increased, except the chlorine and the soda, which are notably diminished, especially the chlorine; the magnesia is also diminished, but in a much less degree. In these experiments, however, the diet was not uniform.

§ Proceedings of Royal Society, No. 94, 1867, p. 52.

‖ For a statment of these experiments up to 1860, I may refer to my work On the Composition of the Urine, 1860, p. 85. Since this time the chief experiments have been by Voit, Pettenkofer, J. Ranke, E. Smith, Haughton, Fick and Wislicenus, Byasson, Noyes, Meissner, Pavy, and others.

¶ Henle's Zeitschrift für rat. Med. band xxxii. p. 233.

** Proceedings of the Royal Med. Society, No. 89 (1867), and No. 94 (1867).

work was actually performed was compared with previous and subsequent equal rest periods. Some experiments were performed on men who took no nitrogen as food; others were on men on a constant diet, so that the variation produced by the altering ingress of nitrogen was avoided as far as possible.

In this place it is impossible to give an account of these long researches, and I must venture on a short summary. (1.) When a period of exercise is compared after an interval with one of rest (the diet being without nitrogen or with uniform nitrogen), the elimination of nitrogen by the kidneys is decidedly not increased in the exercise period. The experiments on this point are now so numerous that it may be stated without doubt. It is possible that the elimination may even be less during the exercise than during the work period. This would appear in part from some of Ranke's and Fick and Wislicenus' experiments; from Noyes, as far as regards the urea; and from Meissner's, as far as the creatin (or creatinine) is concerned; while I found a decrease both in the total nitrogen and in the urea. The decrease in my experiments was not inconsiderable. Additional observations are, however, much wanted on this point.

(2.) When a day of rest is compared with a day of work (*i.e.*, a day with some hours of work and some hours of rest), the amount of nitrogen is almost or quite the same on the two days; if anything there is a slight increase in the nitrogen on the rest day. In a day of part exercise and part rest, it is quite possible that there may be compensatory action, one part balancing the other, so as to leave the total excretion little changed.

(3.) When a period of great exercise is immediately followed by an equal period of rest, the nitrogenous elimination is increased in the latter. Meissner's observations show that this is in part owing to increased discharge of creatin and creatinine; my observations also show an increase of non-ureal nitrogen. But the urea is also slightly increased in this period.

(4.) When two days of complete rest are immediately followed by days of common exercise, the nitrogenous elimination diminishes during the first day of exercise.[*]

On the whole, if I have stated the facts correctly, the effect of exercise is certainly to influence the elimination of nitrogen by the kidneys, but within narrow limits, and the time of increase is in the period of rest succeeding the exercise; while during the exercise period the evidence, though not certain, points rather to a lessening of the elimination of nitrogen.

It would appear from these facts that well-fed persons taking exercise would require a little more nitrogen in the food, and it is certain, as a matter of experience, that persons undergoing laborious work do take more nitrogenous food. This is the case also with animals. The possible reason of this will appear presently.

(*l*) *On the Temperature of the Body.*—As already stated, the temperature of the body, as long as the skin acts, rises little. Dr Clifford-Allbutt,[†] from observations made on himself when climbing the Alps,[‡] found his temperature fairly uniform; the most usual effect was a slight rise, compensated by an

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[*] This fact at presents rests only upon my observations; it has an important bearing on the interpretation of the facts connected with the elimination of nitrogen, and I hope observations by others will soon confirm or disprove it.

[†] Alpine Journal, May 1871.

[‡] In the experiments made by Dr Calberla[*] and his two guides, during their ascents of Monte Rosa and the Matterhorn, in August 1874, no depressions were found as have been recorded by other observers. In none of the three persons did the temperature ever fall below 36°·4 C (=97·5 F.), or rise above 37·8 C. (=100° F.) Dr Thomas of Leipsic, in ascents in Savoy and Dauphiné (3,500 and 3,750 metres) could also find no lowering of temperature.

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[†] Archiv der Heilkunde, 1875, p. 274.

earlier setting in of the evening fall. On two occasions he noticed two curious depressions, amounting to no less than 4°·5 Fahr.; he believes these were due to want of food, and not to exercise *per se.* In experiments on soldiers when marching, I have found no difference in temperature; or if there was a very slight rise, it was subsequently compensated for by an equal fall, so that the mean daily temperature remained the same.[*] A decided rise in temperature during marching would then show lessening of skin evaporation, and may possibly be an important indication of impending sunstroke.

*Changes in the Muscles.*—The discussion on this head involves so many obscure physiological points, that it would be out of place to pursue it here to any length. The chief changes during action appear to be these:—There is a considerable increase in temperature (Helmholtz) which, up to a certain point, is proportioned to the amount of work. It is also proportioned to the kind, being less when the muscle is allowed to shorten than if prevented from shortening (Heidenhain); the neutral or alkaline reaction of the tranquil muscle becomes acid from para-lactic acid and acid potassium phosphate; the venous blood passing from the muscles becomes much darker in colour, is much less rich in oxygen, and contains much more carbonic acid (Sczelkow); the extractive matters soluble in water lessen, those soluble in alcohol increase (Helmholtz, in frogs); the amount of water increases (in tetanus, J. Ranke), and the blood is consequently poorer in water; the amount of albumen in tetanus is less according to Ranke, but Kühne has pointed out that the numbers do not justify this inference.[†] Baron J. von Liebig stated that the creatin is increased (but this was an inference from old observations on the extractum carnis of hunted animals, and requires confirmation). Sarokin has stated the same fact in respect of the frog. The electro-motor currents show a decided diminution during contraction.

That great molecular changes go on in the contracting muscles is certain, but their exact nature is not clear; according to Ludimar Hermann,[‡] there is a jelly-like separation and coagulation of the myosin, and then a resumption of its prior form, so that there is a continual splitting of the muscular structure into a myosin coagulum, carbonic acid, and a free acid, and this constitutes the main molecular movement. But no direct evidence has been given of this.

The increased heat, the great amount of carbonic acid, and the disappearance of oxygen, combined with the respiratory phenomena already noted, all seem to show that an active oxidation goes on, and it is very probable that this is the source of the muscular action. The oxidation may be conceived to take place in two ways—either during rest oxygen is absorbed and stored up in the muscles and gradually acts there, producing a substance which, when the muscle contracts, splits up into lactic acid, carbonic acid, &c.; or, on the other hand, during the contraction an increased absorption of oxygen goes on in the blood and acts upon the muscles, or on the substances in the blood circulating through the muscles.[§] The first view is strengthened by some of Pettenkofer and Voit's experiments, which show that during rest a certain amount of storage of oxygen goes on, which no doubt in part occurs in the muscles themselves. Indeed, it has been inferred that it is this stored up oxygen, and not that breathed in at the time, which is used in muscular action. The increased oxidation gives us a reason why the nitrogenous food must be increased during periods of great exertion. An increase in the supply of oxygen is a necessity for increased muscular action; but Pettenkofer and Voit's observations (see page 188) have shown that the absorption of oxygen is dependent on the amount and action of the nitrogenous structures of the body, so that, as a matter of course, if more oxygen is required for increased muscular work, more nitrogenous food is necessary. But apart from this, although experiments on the amount of nitrogenous elimination show no very great change on the whole, there is no doubt that, with constant regular exercise, a muscle enlarges, becomes thicker, heavier, contains more solid matter, and in fact has gained in nitrogen. This process may be slow, but it is certain; and the nitrogen must either be supplied by increased food, or be taken from other parts.*

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[*] Proceedings of Royal Society, No. 127 and No. 136.

[†] Lehrb. der Phys. Chem. 1866, p. 323.

[‡] Unters. über den Stoffwechsel der Muskeln, von Dr L. Hermann; Weitere Untersuch. zur phys. der Muskeln, von Dr L. Hermann, 1867.

[§] Heaton (Quarterly Journal of Science, 1866) has given strong reasons for believing that the oxidation goes on in the blood.

So that although we do not know the exact changes going on in the muscles, it is, I presume, certain that regular exercise produces in them an addition of nitrogenous tissue.

Whether this addition occurs, as usually believed, in the period of rest succeeding action, when in some unexplained way the destruction which it is presumed has taken place, is not only repaired, but is exceeded (a process difficult to understand), or whether the addition of nitrogen is actually made during the action of the muscle,† must be left undecided for the present.

The substances which are thus oxidised in the muscle, or in the blood circulating through it, and from which the energy manifested, as heat or muscular movement, is believed to be derived, may probably be of different kinds. Under ordinary circumstances the experiments and calculations of Fick and Wislicenus, and others, and the arguments of Traube, seem sufficient to show that the non-nitrogenous substances, and perhaps especially the fats, furnish the chief substances acted upon. But it is probable that the nitrogenous substances also furnish a contingent of energy.‡ The exact mode in which the energy thus liberated by oxidation is made to assume the form of mechanical motion is quite obscure.

### *The Exhaustion of Muscles.*

There seems little doubt that the exhaustion of muscles is chiefly owing to two causes—first, and principally, to the accumulation in them of the products of their own action (especially para-lactic acid); and, secondly, from the exhaustion of the supply of oxygen. Hence rest is necessary, in order that the blood may neutralise and carry away the products of action, so that the muscle recover its neutrality and its normal electrical currents, and may again acquire oxygen in sufficient quantity for the next contraction. In the case of all muscles these intervals of action and of exhaustion take place, in part even in the period which is called exercise, but the rest is not sufficient entirely to restore it. In the case of the heart, the rest between the contractions (about two-thirds of the time), is sufficient to allow the muscle to perfectly recover itself.

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* The way in which a vigorously acting part will rob the body of nitrogen, and thus, in some cases cause death, is seen in many cases of disease. A rapidly growing cancer of the liver, for example, takes so much nitrogen as well as fat that it actually starves the rest of the body, and both voluntary muscles and heart waste. This is the case, though it is less marked, with growing tumours of other parts, and with great discharges. Powerful muscular action, if the food is not increased, evidently acts in something the same way; the health is greatly affected, and the heart especially fails.

† I have suggested, in a Paper in the Proceedings of the Royal Society, No. 94, 1867, this view, which seems to me not only in accordance with the facts of the nitrogenous elimination as far as known, but to agree with Pettenkofer and Voit's experiments on the storing up of the oxygen and its probable action during rest. But I do not think it is desirable, until many more experiments have been made, to accept this view in any other light than an hypothesis. If it be correct, it will have important consequences on the doctrine of nutrition, but it would be premature to use it at present to explain the phenomena of growth and decay.

‡ Pavy shows, in his observations on Weston and Perkins, that the excess of nitrogen eliminated during the walking period, over the period of rest, was equivalent to about 542 foot-tons per man per diem. The total average daily work done, he states, at 1264 foot-tons, but this is an under-estimate, as the velocity was apparently greater than that of average walking, the coefficient of which ($\frac{1}{20}$) he assumes as the proportion of resistance. N.B.—One grain of nitrogen eliminated, represents an amount of albuminate expended, capable of yielding about 2·4 foot-tons of potential energy. Although some of the excess of nitrogen eliminated during exercise, as noted above, may have been due to disintegration of muscle, part of it was due (undoubtedly) to changes in other tissues, but a considerable amount is due to direct oxidation of albuminous food.

The body after exertion eagerly absorbs and retains water; the water, though taken in large quantities, does not pass off as rapidly as usual by the kidneys or the skin, and instead of causing an augmented metamorphosis, as it does in a state of rest, it produces no effect whatever. So completely is it retained, that although the skin has ceased to perspire, the urine does not increase in quantity for several hours. The quantity of water taken is sometimes so great as not only to cover the loss of weight caused by the exercise, but even to increase the weight of the body.

We can be certain, then, of the absolute necessity of water during and after exercise, and the old rule of the trainer, who lessened the quantity of water to the lowest point which could be borne, must be wrong. In fact, it is now being abandoned by the best trainers, who allow a liberal allowance of fluid. The error probably arose in this way: if, during great exertion, water is denied, at the end of the time an enormous quantity is often drunk, more, in fact, than is necessary, in order to still the overpowering thirst. The sweating which the trainer had so sedulously encouraged is thus at once compensated, and, in his view, all has to be done over again. All this seems to be a misapprehension of the facts. The body must have water, and the proper plan is to let it pass in small quantities and frequently; not to deny it for hours, and then to allow it to pass in in a deluge. The plan of giving it in small quantities frequently, does away with two dangers, viz., the rapid passage of a large quantity of cold water into the stomach and blood, and the taking more than is necessary.[*]

In the French army, on the march, the men are directed not to drink; but if very thirsty, to hold water in the mouth, or to carry a bullet in the mouth. It is singular, in that nation of practical soldiers, to find such an order. Soldiers ought to be abundantly supplied with water, and taught to take small quantities, when they begin to feel thirsty or fatigued. If they are hot, the cold water may be held in the mouth a minute or two before swallowing, as a precaution; though, I must say, as far as I have seen, I have never known any ill effects from drinking a moderate quantity of cold water, even during the greatest heat of the body.[†]

*General Effect of Exercise on the Body, as judged of by the preceding facts.*—The main effect of exercise is to increase oxidation of carbon, and perhaps also of hydrogen; it also eliminates water from the body, and this action continues, as seen from Pettenkofer and Voit's experiments, for some time; after exercise, the body is therefore poorer in water, especially the blood; it increases the rapidity of circulation everywhere, as well as the pressure on the vessels, and therefore it causes in all organs a more rapid outflow of plasma and absorption,—in other words, a quicker renewal. In this way also it removes the products of their action, which accumulate in organs; and restores the power of action to the various parts of the body. It increases the outflow of warmth from the body by increasing perspiration. It therefore strengthens all parts. It must be combined with increased supply both of nitrogen and carbon (the latter possibly in the form of fat) otherwise the absorption of oxygen, the molecular changes in the nitrogenous tissues, and the elimination of carbon, will be checked. There must be also an increased supply of salts, certainly of chloride of sodium; probably of potassium phosphate and chloride. There must be proper intervals of rest, or the store of oxygen, and of the material in the muscles which is to be metamorphosed during contraction, cannot take place. The integrity and perfect freedom of action both of the lungs and heart are essential, otherwise neither absorption of oxygen nor elimination of carbon can go on, nor can the necessary increased supply of blood be supplied to the acting muscles without injury.

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[*] It is but right to say that many travellers of great experience have expressed great fear of water under exertion. Some of them have most strongly urged that "water be avoided like poison," and have stated that a large quantity of butter is the best preventive of thirst. At any rate, the butter may be excellent, but a little water is a necessity.

[†] Horses also used to be, and by some are now, deprived or stinted of water during exercise. But in India, the native horsemen give their horses drink as often as they can; and Dr Nicholson tells me this is the case with the Cape horses; even when the horses are sweating profusely, the men will ride them into a river, bathe their sides and allow them to drink.

In all these points, the inferences deducible from the physiological inquiries seem to be quite in harmony with the teachings of experience.

## SECTION II.

## AMOUNT OF EXERCISE WHICH SHOULD BE TAKEN.

It would be extremely important to determine, if possible, the exact amount of exercise which a healthy adult, man or woman, should take. Every one knows that great errors are committed, chiefly on the side of defective exercise. It is not, however, easy to fix the amount even for an average man, much less to give any rule which shall apply to all the divers conditions of health and strength. But it is, I think, certain that muscular work is not only a necessity for health of body, but for mind also; at least it has seemed to me that diminution in the size of the body from deficient muscular work seems to lead in two or three generations to degenerate mental formation.

The external work which can be done by a man daily has been estimated at $\frac{1}{7}$th of the work of the horse; but if the work of a horse is considered to be equal to the 1-horse power of a steam engine (viz., 33,000 ℔ raised 1 foot high per minute, or 8839 tons raised 1 foot high in ten hours), this must be an over-estimate, as $\frac{1}{7}$th of this would be 1263 tons raised 1 foot in a day's work of ten hours.* The hardest day's work of twelve hours I have ever

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* In some works on physiology a man's work of eight hours has been put as high as 316,800 kilogrammemetres, or 1020 tons lifted a foot; but this is far too much.

In this country, the amount of work done is generally estimated as so many ℔s. or tons lifted 1 foot. In France it is expressed as so many kilogrammes lifted 1 metre. Kilogrammemetres are converted into foot-pounds, by multiplying by 7·233. To bring at once into tons lifted a foot, multiply kilogrammemetres by ·003229. The following table may be useful, as expressing the amount of work done. It is taken from Dr Haughton's work (A New Theory of Muscular Action). The numbers are a little different from those given by Coulomb, as they were recalculated by Dr Haughton in 1863.

**Labouring Force of Man.**

| Kind of Work. | Amount of Work. | Authority. |
|---|---|---|
| Pile driving, . . . . | 312 tons lifted 1 foot. | Coulomb. |
| Pile driving, . . . . | 352 ,, ,, | Lamande. |
| Turning a winch, . . . . | 374 ,, ,, | Coulomb. |
| Porters carrying goods and returning unladen, . . . . | 325 ,, ,, | ,, |
| Pedlars always loaded, . . . | 303 ,, ,, | ,, |
| Porters carrying wood up a stair and returning unloaded, . . . | 381 ,, ,, | ,, |
| Paviours at work, . . . . | 352 ,, ,, | Haughton. |
| Military prisoners at shot drill (3 hours), and oakum picking, and drill, . . | 310 ,, ,, | ,, |
| Shot drill alone (3 hours), . . | 160·7 ,, ,, | ,, |

myself known a man do, was in the case of a workman in a copper rolling-mill. He stated that he occasionally raised a weight of 90 ℔ to a height of 18 inches, 12,000 times a-day. Supposing this to be correct, he would raise 723 tons 1 foot high. But this much overpasses the usual amount. The same man's ordinary day's work, which he considered extremely hard, was raising a weight of 124 ℔ 16 inches, 5000 or 6000 times in a day. Adopting the larger number, this would make his work equivalent to 442·8 tons lifted a foot; and this was a hard day's work for a powerful man. Some of the puddlers in the iron country, and the glass-blowers, probably work harder than this; but I am not aware of any calculations. I learned from a pedlar, that an ordinary day's work was to carry 28 ℔ twenty miles daily. The weight is balanced over the shoulder,—14 ℔ behind and 14 ℔ in front. The work is equal to 419·5 tons lifted 1 foot. It would, therefore, seem certain that an amount of work equal to 500 tons lifted a foot is an extremely hard day's work, which perhaps few men could continue to do. 400 tons lifted a foot is a hard day's work, and 300 tons lifted a foot is an average day's work for a healthy, strong adult.

The external work is thus 300 to 500 tons on an average; the internal work of the heart, muscles of respiration, digestion, &c., has been variously estimated; the estimates for the heart alone vary from 122 to 277 tons lifted a foot. The former is that given by Haughton, who estimates the respiratory movements as about 11 tons lifted a foot in 24 hours. Adopting a mean number of 260 tons for all the internal mechanical work, and the external work of a mechanic being 300 to 500 tons, this will amount to from $\frac{1}{7}$th to $\frac{1}{8}$th of all the force obtainable from the food.

The exertion which the infantry soldier is called upon to undergo is chiefly drill and carrying weights on a level, or over an uneven surface.

The Reverend Professor Haughton, M.D., who is so well known for his important contributions to physiology and medicine, has shown that walking on a level surface at the rate of about 3 miles an hour is equivalent to raising $\frac{1}{20}$th part of the weight of the body through the distance walked; an easy calculation changes this into the weight raised 1 foot. When ascending a height, a man of course raises his whole weight through the height ascended.

Using this formula,* and assuming a man to weigh 150 ℔ with his clothes, we get the following table:—

| | |
|---|---|
| Walking 1 mile, . . . . . . | 17·67 |
| " 2 " . . . . . . . | 35·34 |
| " 10 " . . . . . . . | 176·7 |
| " 20 " . . . . . . . | 353·4 |
| " 1 " and carrying 60 ℔, . . | 24·75 |
| " 2 " " . . | 24·75 |
| " 10 " " . . | 247·5 |
| " 20 " " . . | 495 |

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It may be interesting to give some examples of work done in India by natives, which have been given me by Dr de Chaumont:—

A Leptcha hill-coolie will go from Punkabarree to Darjeeling (thirty miles, and an ascent of 5500 feet), in three days, carrying 80 ℔ weight, the weight is carried on a frame supported on the loins and sacrum, and aided by a band passed round the forehead.

Work per diem, 500 tons lifted 1 foot.

Eight palanquin bearers carried an officer weighing 180 ℔, and palanquin weighing 250 ℔, twenty-five miles in Lower Bengal. Assuming each man weighed 150 ℔ the work was 600 tons lifted a foot.

* The formula is $\frac{(W + W') \times D}{20 \times 2240}$; where W is the weight of the person, W' the weight carried; D the distance walked in feet; 20 the coefficient of traction; and 2240 the number of

It is thus seen that a march of ten miles, with a weight of 60 lb (which is nearly the weight a soldier carries when in marching order, but without blankets and rations), is a moderate day's work. A twenty-miles' march, with 60 lb weight, is a very hard day's work. As a continued labouring effort, Dr Haughton believes that walking twenty miles a-day, without a load (Sunday being rest), is good work (353 tons lifted a foot); so that the load of 60 lb additional would make the work too hard for a continuance.*

It must, however, be remembered, that it is understood that the walking is on level ground, and is done in the easiest manner to the person, and that the weights which are carried are properly disposed. The labour is greatly increased if the walk is irksome, and the weights are not well adjusted. And this is the case with the soldier. In marching, his attitude is stiff; he observes a certain time and distance in each step; he has none of those shorter and longer steps, and slower and more rapid motion, which assist the ordinary pedestrian. It may be questioned, indeed, whether the formula does not under-estimate the amount of work actually done by the soldier. The work becomes heavier, too, *i.e.*, more exhausting, if it is done in a shorter time; or, in other words, velocity is gained at the expense of carrying power.† The velocity in fact, *i.e.*, the rate at which work is done, is an important element in the question, in consequence of the strain thrown on the heart and lungs. The Oxford boat races—rowing at racing speed (= 1 mile in 7 minutes) in an Oxford eight-oar, or 18·56 foot-tons in 7 minutes‡ is not apparently very hard

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pounds in a ton. The result is the number of tons raised 1 foot. To get the distance in feet, multiply 5280 by the number of miles walked.

* I calculated the work done by the sledge-parties in the Arctic Expedition of 1875–6, and found that the Northern party (Markham's), did a mean of 574 foot-tons per man per diem, with a maximum of 859; the Western party (Aldrich's) did a mean of 448, and a maximum of over 600. Even this large amount was considered an under-estimate by the Commanders. (See Report of Committee on Outbreak of Scurvy (Blue Book) App. 24, p. 365). [F. de C.]

† Dr Haughton (Principles of Animal Mechanics, 2d ed. pp. 56 and 57) has determined, from the calculations of the MM. Weber, the coefficient of resistance for three velocities, as follows:—

| Miles per Hour. | Co-efficient of Resistance. |
|---|---|
| 1·818 | [illegible] |
| 4·353 | [illegible] |
| 10·577 | [illegible] |

Interpolating between these numbers we can obtain the coefficients at other velocities. The following table shows the coefficients, the distance in miles that would equal 300 foot-tons for a man of 160 lbs, and the time in hours and minutes that would be required without rest:—

| Velocity in Miles per Hour. | Co-efficient of Resistance. | Distance for Men of 160 lb, to equal 300 foot-tons. | Time required in Hours and Minutes. H. | M. |
|---|---|---|---|---|
| 2 | [illegible] | 21·2 | 10 | 36 |
| 3 | [illegible] | 16·3 | 5 | 24 |
| 4 | [illegible] | 13·3 | 3 | 18 |
| 5 | [illegible] | 11·2 | 2 | 36 |
| 6 | [illegible] | 9·6 | 1 | 36 |
| 7 | [illegible] | 8·5 | 1 | 12 |
| 8 | [illegible] | 7·6 | 0 | 57 |
| 9 | [illegible] | 6·9 | 0 | 46 |
| 10 | [illegible] | 6·3 | 0 | 38 |

The coefficient $\frac{1}{20}$ corresponds very nearly to 3·1 miles an hour, and this appears to be the rate at which the greatest amount of work can be done at the least expenditure of energy. (See Table XVIII., p. 186, Lectures on State Medicine, by F. de Chaumont.) As regards velocity, Dr Haughton states the "Law of Fatigue" as follows:—"When the same muscle (or group of muscles) is kept in constant action till fatigue sets in, the total work done, multiplied by the rate of work, is constant." The "Law of Refreshment" depends on the rate at which arterial blood is supplied to the muscles, and the "Coefficient of Refreshment" is the work restored to the muscles in foot-pounds per ounce of muscle per second; for voluntary muscle it is on an average 0·1309, and for the heart 0·2877, or exactly equal to the work of the heart, which never tires. [F. de C.]

‡ Training, by A. Maclaren, p. 163.

work, but it is very severe for the time, as its effect is great on the circulatory system.

Looking at all these results, and considering that the most healthy life is that of a man engaged in manual labour in the free air, and that the daily work will probably average from 250 to 350 tons lifted 1 foot, we can perhaps say, as an approximation, that every healthy man ought, if possible, to take a daily amount of exercise in some way, which shall not be less than 150 tons lifted 1 foot. This amount is equivalent to a walk of about 9 miles; but then, as there is much exertion taken in ordinary business of life, this amount may be in many cases reduced. It is not possible to lay down rules to meet all cases; but probably every man with the above facts before him could fix the amount necessary for himself with tolerable accuracy.

In the case of the soldier, if he were allowed to march easily, and if the weights were not oppressively arranged, he ought to do easily 12 miles daily for a long time, provided he was allowed a periodical rest. But he could not for many days, without great fatigue, march 20 miles a day with a 60 lb load, unless he were in good condition and well fed. If a greater amount still is demanded from him, he must have long subsequent rest. But all the long marches by our own or other armies have been made without weights, except arms and a portion of ammunition. Then great distances have been traversed by men in good training and condition.

## SECTION III.

## TRAINING.

The aim of the "Trainer" is to increase breathing power; to make the muscular action more vigorous and enduring, and to lessen the amount of fat. He arrives at his result by a very careful diet, containing little or no alcohol; by regular and systematic exercise; and by increasing the action of the eliminating organs, especially of the skin.

What the "Trainer" thus accomplishes is in essence the following: a concordant action is established between the heart and blood-vessels, so that the strong action of the heart during exercise is met by a more perfect dilatation of the vessels, and there is no blockage of the flow of blood; in the lungs, the blood not only passes more freely, but the amount of oxygen is increased, and the gradual improvement in breathing power is well seen when horses are watched during training. This reciprocal action of heart and blood-vessels is the most important point in training; the nutrition of nerves and muscular fibres improves from the constant action, and the abundant supply of food; the tissue changes are more active, and elimination, especially of carbon, increases. A higher condition of health ensues, and if not carried to excess, "training" is simply another word for healthy and vigorous living.*

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* Of course, over-training may be hurtful, but anything can be carried too far. I can only refer to Dr Morgan's highly interesting and well-worked out treatise on University Oars, to show that rowing is beneficial. Dr Lee has published a useful little book, Exercise and Training, by R. Lee, M.D., with some good advice on training.

# CHAPTER XIII.

# CLOTHING.

The objects of clothing are to protect against cold and against warmth; all other uses will be found to resolve themselves into one or other of these.

The subject naturally divides itself into two parts—*1st*, The materials of clothing; and *2d*, The make of the garments, which will be considered in Book II., and only as far as the soldier is concerned.

## Materials of Clothing.

The following only will be described:—Cotton, linen, jute, wool, leather, and india-rubber.

*Chemical Reaction.*—These materials are all easily distinguished by microscopical characters, but certain chemical reactions may be useful. Wool and silk dissolve in boiling liquor potassæ or liquor sodæ of sp. gr. 1040 to 1050; cotton and linen are not attacked. Wool is little altered by lying in sulphuric acid, but cotton and linen change in half an hour into a gelatinous mass, which is coloured blue by iodine. Silk is slowly dissolved. Wool and silk take a yellow colour in strong nitric acid; cotton and linen do not. So also wool and silk are tinged yellow by picric acid; cotton and linen are not, or the colour is slight, and can be washed off. Silk, again, is dissolved by hot concentrated chloride of zinc, which will not touch wool. In a mixed fabric of silk, wool, and cotton, first boil in strong chloride of zinc, and wash; this gets rid of the silk; then boil in liquor sodæ, which dissolves the wool, and the cotton is left behind. Another reagent is recommended by Schlesinger, viz., a solution of copper in ammonia; this rapidly dissolves silk and cotton, and, after a longer time, linen; wool is only somewhat swollen by it. By drying thoroughly first, and after each of the above steps, the weight of the respective materials can be obtained.*

*Cotton—Microscopic Characters.*—A diaphanous substance forming fibres about $\frac{1}{1000}$th of an inch in diameter, flattened in shape, and riband-like, with an interior canal which is often obliterated, or may contain some extractive matters, borders a little thickened, the fibres twisted at intervals (about 600 times in an inch). It has been stated that the fresh cotton fibre is a cylindrical hair with thin walls, which collapses and twists as it becomes dry. Iodine stains them brown; iodine and sulphuric acid (in very small quantities) give a blue or violet blue; nitric acid does not destroy them, but unrolls the twists.

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* If other fabrics than those mentioned in the text have to be examined, the best book to consult is Dr Schlesinger's Mikroscopische Untersuch. der Gespinnst-Fasern (Zurich, 1873), where plates will be found of many of the fibres of commerce. The following are the chief reagents used by Schlesinger:—*1st*, strong and weak sulphuric acid, to dissolve or swell out the fibres, and also, with iodine, to test for cellulose. *2d*, Nitric acid, especially to show the markings. *3d*, Chromic acid, as the best solvent for the intercellular substance, and for the swelling out in solution of the cellulose; it is often used with sulphuric acid. *4th*, Dilute tincture of iodine, which is added to cellulose, and then sulphuric acid is used. *5th*, Solution of copper, made by disolving metallic copper in ammonia; this dissolves cell-membrane. *6th*, Sulphate of aniline, which colours lignite yellow. *7th*, Liquor potassæ (dilute), to render the fabrics transparent. He advises the fabric to be put on a slip of glass, and then a drop of water to be placed on it; then a needle should be drawn two or three times in the direction of the fibres, which will be easily detached. Then the fibre is laid on a glass and the reagent is applied.

*As an Article of Dress.*—The fibre of cotton is exceedingly hard, it wears well, does not shrink in washing, is very non-absorbent of water (either into its substance, or between the fibres), and conducts heat rather less rapidly than linen, but much more rapidly than wool.*

The advantages of cotton are cheapness and durability; its hard non-absorbent fibre places it far below wool as a warm water-absorbing clothing. In the choice of cotton fabrics there is not much to be said; smoothness, evenness of texture, and equality of spinning, are the chief points.

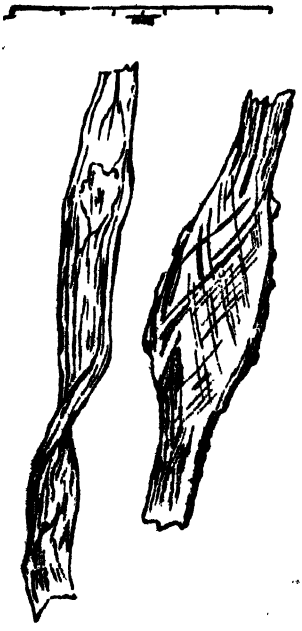

Fig. 99.—Cotton × 285.

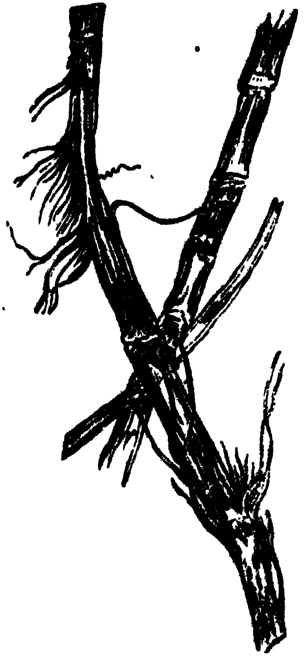

Fig. 100.—Linen × 285.

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* Late experiments have been made on the conducting power of materials by Coulier (Professor of Chemistry at the Val de Grâce), and by Dr Hammond (late Surgeon-General, United States Army). In both cases a polished metallic vessel was filled with hot water of a known temperature, a delicate thermometer inserted, and the vessel was hung in an empty room; the time required for cooling to a given point, when the vessel was uncovered and covered by different fabrics, was noted by the observer at a distance with a magnifying glass.

*Coulier's Experiments.*
Time required for cooling from 122° Fahr. to 104° Fahr.

| | Min. | Sec. |
|---|---|---|
| Vessel uncovered, . . . . | 18 | 12 |
| " covered with cotton shirting, | 11 | 30 |
| " " " linings, | 11 | 15 |
| " " hemp lining, | 11 | 25 |
| " " blue woollen cloth for uniforms, | 14 | 45 |
| " " red do., for uniforms, . | 14 | 50 |
| " " blue do., for great-coats, . . | 15 | 5 |

*Hammond's Experiments.*
Time required for cooling from 150° Fahr. to 140° Fahr.

| | Min. | Sec. |
|---|---|---|
| Vessel uncovered, . . . . | 15 | 11 |
| " covered with cotton shirting, | 9 | 42 |
| " " linen shirting, | 7 | 24 |
| " " white flannel, | 12 | 35 |
| " " dark blue woollen cloth, . | 14 | 5 |
| " " light blue woollen cloth, . | 13 | 30 |

In cotton shirting and calico, cotton is alone used; in merino and other fabrics it is used with wool, in the proportion of 20 to 50 per cent. of wool, the threads being twisted together to form the yarn.

*Linen—Microscopic Characters.*—The fibres are finer than those of cotton, diaphanous, cylindrical, and presenting little swellings at tolerably regular intervals. The elementary fibres (of which the main fibre is composed) can be often seen in these swellings, and also at the end of broken threads which have been much used. The hemp fibre is something like this, but much coarser, and at the knots it separates often into a number of smaller fibres. Silk is a little like linen, but finer, and with much fewer knots.

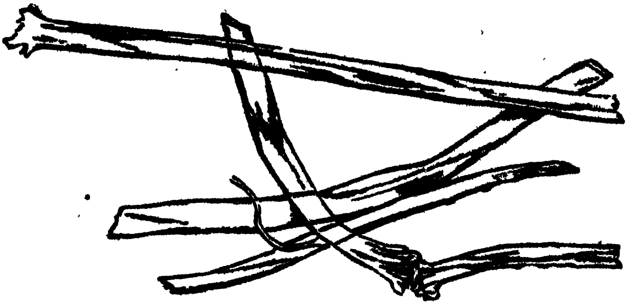

Fig. 101.—Silk × 285. Scale on page 424.

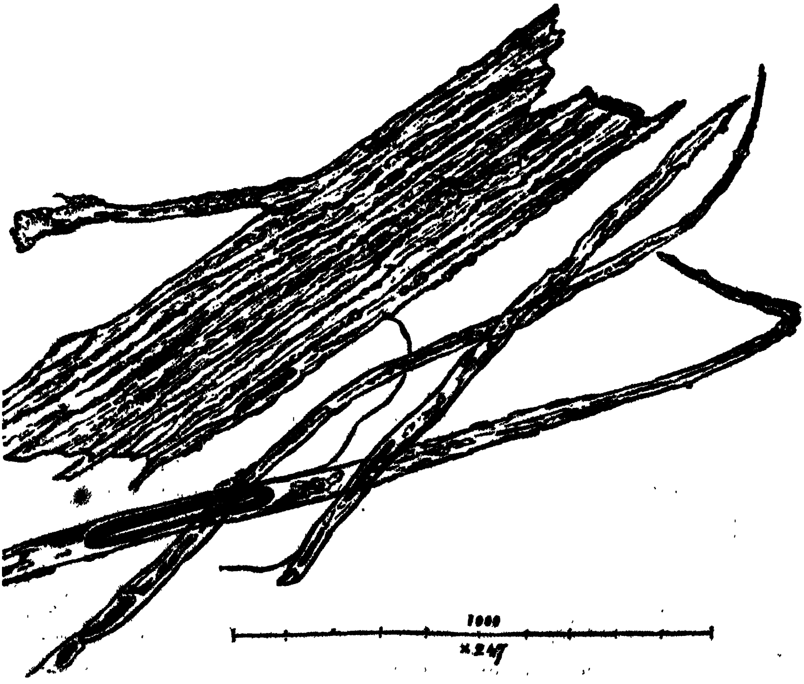

Fig. 102.—Jute—United and single elongated cellular tissues. Resinous (?) matter adhering more or less to all the fibres.

*As an Article of Clothing.*—Linen conducts heat and absorbs water slightly better than cotton. It is a little smoother than cotton. As an article of clothing it may be classed with it. In choosing linen regard is had to the evenness of the threads, and to the fineness and closeness of the texture. The colour should be white, and the surface glossy. Starch is often used to give glossiness. This is detected by iodine, and removed by the first washing.

*Jute.*—As jute is now being very largely used, it is possible it may be employed as a falsification of linen or cotton. Jute is obtained from the *Corchorus capsularis*, and comes to England from Russia and India. The fibres are of considerable length, are hollow, thickened, and with narrowings and constrictions in the tubular portions; sometimes an air-bubble may be in the fibre, as shown in the drawing. The drawing, which, as well as the above description, I owe to Dr Maddox, shows the differences between the jute and cotton or linen.

*Wool—Microscopic Characters.*—Round fibres, transparent or a little hazy, colourless. The fibre is made up of a number of little cornets, which have become united. There are very evident slightly oblique cross markings, which indicate the bases of the cornets; and at these points the fibre is very slightly larger. There are also fine longitudinal markings. There is a canal, but it is often obliterated. When old and worn, the fibre breaks up into fibrillæ; and, at the same time, the slight prominence at the cross markings disappear, and even the markings become indistinct. By these characters old wool can be recognised. Size of fibres varies, but an average is given by the figure. The finest wools have the smallest fibres.

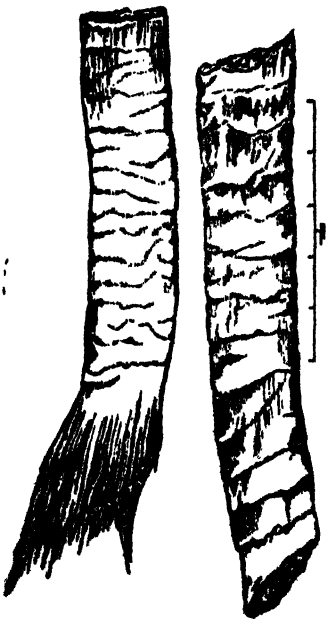

Fig. 103.—Wool × 285.
Scale, $\frac{1}{1000}$th inch.

*As an Article of Clothing.*—Wool is a bad conductor of heat and a great absorber of water. The water penetrates into the fibres themselves and distends them (hygroscopic water), and also lies between them (water of interposition). In these respects it is greatly superior to either cotton or linen, its power of hygroscopic absorption being at least double in proportion to its weight, and quadruple in proportion to its surface.

This property of hygroscopically absorbing water is a most important one. During perspiration the evaporation from the surface of the body is necessary to reduce the heat which is generated by the exercise. When the exercise is finished, the evaporation still goes on, and, as already noticed, to such an extent as to chill the frame. When dry woollen clothing is put on after exertion, the vapour from the surface of the body is condensed in the wool, and gives out again the large amount of heat which had become latent when the water was vaporised. Therefore a woollen covering, from this cause alone, at once feels warm when used during sweating. In the case of cotton and linen the perspiration passes through them, and evaporates from the external surface without condensation; the loss of heat then continues. These facts make it plain why dry woollen clothes are so useful *after* exertion.*

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* Pettenkofer gives (Zt. für Biol. band i. p. 185) some experiments showing the hygroscopic power of wool as compared with linen. He shows that linen not only absorbs much less water,

In addition to this, the texture of wool is warmer, from its bad conducting power, and it is less easily penetrated by cold winds. The disadvantage of wool is the way in which its soft fibre shrinks in washing, and after a time the fibre becomes smaller, harder, and probably less absorbent.*

In the choice of woollen underclothing the touch is a great guide. There should be smoothness and great softness of texture; to the eye the texture should be close; the hairs standing out from the surface of equal length, not long and straggling. The heavier the substance is, in a given bulk, the better. In the case of blankets, the softness, thickness, and closeness of the pile, the closeness of the texture, and the weight of the blanket, are the best guides.

In woollen cloth the rules are the same. When held against the light, the cloth should be of uniform texture, without holes; when folded and suddenly stretched, it should give a clear ringing note; it should be very resistent when stretched with violence; the "tearing power" is the best way of judging if "shoddy" (old used and worked-up wool and cloth) has been mixed with fresh wool. A certain weight must be borne by every piece of cloth. At the Government Clothing Establishment at Pimlico, a machine is used which marks the exact weight necessary to tear across a piece of cloth. Schlesinger recommends the following plan for the examination of a mixed fabric containing shoddy:—Examine it with the microscope, and recognise if it contains cotton, or silk or linen, besides wool. If so, dissolve them by ammoniacal solution of copper. In this way a qualitative examination is first made. Then fix attention on the wool. In shoddy both coloured and colourless wool-fibres are often seen, as the fibres have been derived from different cloths which have been partially bleached; the colouring matter, if it remains, is different—indigo, purpurin, or madder. The diameter of the wool is never so regular as in fresh wool, and it changes suddenly or gradually in diameter, and suddenly widens again with a little swelling, and then thins off again; the cross marking or scales are also almost obliterated. When liquor potassæ is applied the shoddy wool is attacked much more quickly than fresh wool.

The dye also must be good, and of the kind named in the contract, and tests must be applied.

*Leather.*—Choice of leather; it should be well tanned, and without any marks of corrosion, or attacks of insects. The thinner kind should be perfectly supple.

Leather is not only used for shoes, leggings, and accoutrements; it is employed occasionally for coats and trousers. It is an extremely warm clothing, as no wind blows through it, and is therefore well adapted for cold, windy climates. Leather or sheepskin coats are very common in Turkey, Tartary, Persia, the Danubian Provinces, and everywhere where the cold north winds

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but parts with it much more quickly; thus, to cite one experiment, equal surface of linen and flannel being exposed to the air after being placed in equal conditions of absorption, the linen lost in 75 minutes 5·993 grammes, and the flannel only 4·858 grammes of water. Subsequently the evaporation from the linen lessened, as was to be expected, as it was becoming drier; that from the flannel continued to pass off moderately. The much greater cooling effect of linen is seen.

The porosity of clothing, *i.e.*, the rapidity through which air is driven through, is a point to be noted. By an equal pressure equivalent to a column of water 4·5 centimetres high, an area of 1 centimetre diameter forced air through as follows:—Through linen, 6·08 litres; flannel, 10·41; lambskin, 6·07; glove-leather, ·15: wash-leather, 5·37; silk fabric, 4·14.

It thus appears that the warmest clothing (flannel) may be the most porous; mere porosity in fact, is only one element in the consideration.

* In washing woollen articles, they should never be *rubbed or wrung.* They should be placed in a hot solution of soap, moved about, and then plunged into cold water, when the soap is got rid of they should be hung up to dry without wringing.

are felt. In Canada, coats of sheepskin or buffalo-hide have been found very useful, and are commonly used by sentries.

*Waterproof Clothing.*—Like leather articles, the india-rubber is an exceedingly hot dress, owing to the same causes, viz., impermeability to wind, and condensation and retention of perspiration. It is objected to by many on these grounds, and especially the latter; and Lévy informs us that the Council of Health of the French Army have persistently refused (and, in his opinion, very properly) the introduction of waterproof garments into the army. If, however, woollen underthings are worn, the perspiration is sufficiently absorbed by those during the comparatively short time waterproof clothing is worn, and the objection is properly not valid, unless the waterproof is continually worn.

The great use of waterproof is, of course, its protection against rain, and in this respect it is invaluable to the soldier, and should be largely used. By the side of this great use, all its defects appear to me to be minor evils.

India-rubber cloth loses in part its distensibility in very cold countries, and becomes too distensible in the tropics. Paraffined cloth is equally good, and the paraffin does not rot the fibre like common oil.

### *General Conclusions.*

*Protection against Cold.*—For equal thicknesses, wool is much superior to either cotton or linen, and should be worn for all underclothing. In case of extreme cold, besides wool, leather, or waterproof clothing is useful. Cotton and linen are nearly equal.

*Protection against Heat.*—Texture has nothing to do with protection from the direct solar rays; this depends entirely on colour. White is the best colour; then grey, yellow, pink, blue, black. In hot countries, therefore, white or light-grey clothing should be chosen.

In the shade, the effect of colour is not marked. The thickness, and the conducting power of the material, are the conditions (especially the former) which influence heat.

*Protection against Cold Winds.*—For equal thicknesses, leather and india-rubber take the first rank; wool the second; cotton and linen about equal.

*Absorption of Perspiration.*—Wool has more than double the power of cotton and linen.

*Absorption of Odours.*—This partly depends on colour; and Stark's observations show that the power of absorption is in this order—black, blue, red, green, yellow, white. As far as texture is concerned, the absorption is in proportion to the hygroscopic absorption, and wool therefore absorbs more than cotton or linen.

*Protection against Malaria.*—It has been supposed that wearing flannel next the skin lessens the risk of malaria. As it is generally supposed that the poison of malaria enters either by the lungs or stomach, it is difficult to see how protection to the skin can prevent its action; except indirectly, by preventing chill in persons who have already suffered from ague. But the very great authority of Andrew Combe, drawn from experience at Rome, is in favour of its having some influence; and it has been used on the west coast of Africa for this purpose, with apparently good results.

# CHAPTER XIV.

# CLIMATE.

It is not easy to give a proper definition of climate. The effect of climate on the human body is the sum of the influences which are connected either with the solar agencies, the soil, the air, or the water of a place, and as these influences are in the highest degree complex, it is not at present possible to trace out their effects with any certainty.

With regard generally to the effect of climate on human life, it would seem certain that the facility of obtaining food (which is itself influenced by climate), rather than any of the immediate effects of climate, regulates the location of men and the amount of population. The human frame seems to acquire in time a wonderful power of adaptation; the Esquimaux, when they can obtain plenty of food, are large strong men (though nothing is known of their average length of life), and the dwellers in the hottest parts of the world (provided there is no malaria, and that their food is nutritious) show a stature as lofty, and a strength as great, as any dwellers in temperate climates. Peculiarities of race, indeed, arising no one knows how, but probably from the combined influences of climate, food, and customs, acting through many ages, appear to have more effect on stature, health, and duration of life, than climate alone. Still, it would seem probable that, in climatic conditions so diverse, there arise some special differences of structure which are most marked in the skin, but may possibly involve other organs.

How soon the body, when it has become accustomed by length of residence for successive generations to one climate, can accommodate itself to, or bear the conditions of, the climate of another widely different place, is a question which can only be answered when the influences of climate are better known. The hypothesis of "acclimatisation" implies that there is at first an injurious effect produced, and then an accommodation of the body to the new conditions within a very limited time; that, for example, the dweller in northern zones passing into the tropics, although he at first suffers, acquires in a few years some special constitution which relieves him from the injurious consequences which, it is supposed, the change at first brought with it. There are, therefore, two assumptions, viz., of an injurious effect, and of a relief from it. Are either correct?

It may seem a bold thing to question the commonly received opinion, that a tropical climate is injurious to a northern constitution, but there are some striking facts which it is difficult to reconcile with such an opinion. The army experience shows that, both in the West Indies and in India, the mortality of the soldier has been gradually decreasing, until, in some stations in the West Indies (as, for example, Trinidad and Barbadoes), the sickness and mortality among the European soldiers are actually less than on home service in years which have no yellow fever. In India, a century ago, people spoke with horror of the terrible climate of Bombay and Calcutta, and yet Europeans now live in health and comfort in both cities. In Algeria the French experience is to the same effect. As the climate and the stations are the same, and the soldiers are of the same race and habits, what has removed the dangers which formerly made the sickness threefold and the mortality tenfold the ratio of the sickness and deaths at home?

The explanation is very simple; the deaths in the West Indies were partly owing to the virulence of yellow fever (which was fostered, though probably not engendered by bad sanitary conditions), and the general excess of other febrile and dysenteric cases. The simple hygienic precautions which are efficacious in England have been as useful in the West Indies. Proper food, good water, pure air, have been supplied, and, in proportion as they have been so, the deadly effects attributed to climate have disappeared. The effect of a tropical climate is, so to speak, relative. The temperature and the humidity of the air are highly favourable to decompositions of all kinds; the effluvia from an impure soil, and the putrescent changes going on in it, are greatly aggravated by heat. The effects of the sanitary evils which, in a cold climate like Canada, are partly neutralised by the cold, are developed in the West Indies, or in tropical India, to the greatest degree. In this way a tropical climate is evidently most powerful, and it renders all sanitary precautions tenfold more necessary than in the temperate zone. But all this is not the effect of climate, but of something added to climate.

Take away these sanitary defects, and avoid malarious soils or drain them, and let the mode of living be a proper one, and the European soldier does not die faster in the tropics than at home.*

It must be said, however, that an element of uncertainty may be pointed out here. In our tropical possessions the European soldier serves now only for short periods (in the West Indies for three or four years, in India only for twelve years, and under the new regulations of short service he may only be six years, or less), and during this time he may be for some years on the hills, or at any rate in elevated spots. The old statistical reports of the army pointed out that the mortality in the West Indies augmented regularly with prolongation of service, and it may be said that, after all, the lessened sickness and mortality in the tropics is owing, in some degree, to avoidance by short service of the influence of climate. But as the whole long service was constantly passed under the unfavourable sanitary conditions now removed, it does not follow that the inference to be drawn from the statistical evidence as to length of service is really correct.

Facts prove, then, that under favourable sanitary conditions (general and personal), Europeans, during short services, may be as healthy as at home, as far as shown by tables of sickness and mortality,† and it is not certain that long service brings with it different results.

It may, however, be urged that, admitting that a non-malarious tropical climate *per se*, may not increase sickness or mortality during the most vigorous years of life (and it is then only that Europeans are usually subjected to it), it may yet really diminish health, lessen the vigour of the body, and diminish the expectation of life.

We have no evidence on the latter point.‡ With respect to the former, it will be well to see what is known of the effects of climatic agencies on the frame.

The influences of locality and climate, as far as they are connected with soil and water, have been sufficiently discussed. I shall merely briefly review the climatic conditions most closely (though by no means solely) connected with air. They are—temperature, humidity, movement, weight, composition, and electrical condition. The amount of light is another climatic condition of importance.

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* The production of liver disease in such an amount in India, will be considered by some to be a pure effect of climate. But on this point the evidence seems to me to point most strongly in another direction (see chapter on the Prevention of Disease).

† For the statistical proofs, see the chapters on the West Indies and India.

‡ The tables of the Indian Sanitary Commission, as applying to men who had been under the unfavourable sanitary conditions which prevailed more or less in India till within the last few years, can hardly be used with safety to settle this point.

## SECTION I.

### TEMPERATURE.*

The amount of the sun's rays; the mean temperature of the air; the variations in temperature, both periodic and non-periodic; and the length of time a high or low temperature lasts, are the most important points. Temperature alone has been made a ground of classification.

(*a*) Equable, limited, or insular climates; *i.e.*, with slight yearly and diurnal variations.

(*b*) Extreme, excessive, or continental; *i.e.*, with great variations.

The terms limited and extreme might be applied to the amplitude of the yearly fluctuation (*i.e.*, difference between hottest and coldest month, see METEOROLOGY), while equable and excessive might be applied especially to the non-periodic variations, which are slight in some places, and extreme in others.

A limited climate is generally an equable one, and an extreme climate (with great yearly fluctuation) is generally an excessive one (with great undulations).

The effects of heat cannot be dissociated from the other conditions; it is necessary, however, to briefly notice them.

The effect of a certain degree of temperature on the vital processes of a race dwelling generation after generation on the same spot, is a question which has as yet received no sort of answer. Does the amount of heat *per se*, independent of food and all other conditions, affect the development of mechanical force and temperature, and the coincident various processes of formation and destruction of the tissues? Is there a difference in these respects, and in the resulting action of the eliminating organs, in the inhabitants of the equator and of 50° or 60° N. lat.? This is entirely a problem for the future, but there is no class of men who have more opportunities of studying it than the army surgeons.

The problem of the influence of temperature is generally presented to us under the form of a dweller in a temperate zone proceeding to countries either colder or hotter than his own. It is in this restricted sense I shall now consider it.

With regard to the effect on the Anglo-Saxon and Celtic races of going to live in a climate with a lower mean temperature and greater variations than their own, we have the experience of Canada, Nova Scotia, and some parts of the Northern American States. In all these, if food is good and plentiful, health is not only sustained, but is perhaps improved. The agricultural and out-door life of Canada or Nova Scotia is probably the cause of this; but certain it is that in those countries the European not only enjoys health, but produces a progeny as vigorous, if not more so, than that of the parent race.

The effects of heat exceeding the temperate standard must be distinguished according to origin; radiant heat or the direct rays of the sun, and non-radiant heat, or that of the atmosphere. In the latter case, in addition to heat there is more or less rarefaction of the air, and also coincident conditions of humidity and movement of the air, which must be taken into account. The influence, again, of sudden transitions from heat to cold, or the reverse, has to be considered. The Europeans from temperate climates flourish, apparently, in countries not much hotter than their own, as in some parts of Australia, New Zealand, and New Caledonia, though it is yet too soon to speculate whether the vigour of the race will improve or otherwise. But there is a general impression that they do not flourish in countries much hotter, *i.e.*, with a yearly mean of 20° Fahr. higher, as in many parts of India; that the race dwindles, and finally dies out; and therefore that no acclimatisation of race occurs. And certainly it would appear that, in India, there is some evidence to show that the pure race, if not intermixed with the native, does not reach beyond the third generation. Yet it seems only right to say that so many circumstances besides heat and the other elements of climate have been acting on the English race in India, that any conclusion opposed to acclimatisation must be considered as based on scanty evidence. We have not gauged on a large scale the effects of climate pure and simple, uncomplicated with malaria, bad diet, and other influences adverse to health and longevity.*

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* For some elementary facts on temperature, see METEOROLOGY.

(*a*) *Influence of the Direct Rays of the Sun.*—It is not yet known to what temperature the direct rays of the tropical sun can raise any object on which they fall. In India, on the ground, the uncovered thermometer will mark 160°, and perhaps 212° (Buist); and in this country, if the movement of air is stopped in a small space, the heat in the direct sun's rays can be raised to the same point. In a hermetically sealed box, with a glass top, Sir H. James found the thermometer mark 237° Fahr., when exposed to the rays of the sun, on the 14th July 1864. In experiments on frogs, when temperature much over the natural amount is applied to nerves, the electrical currents through them are lessened, and at last stop.† E. H. Weber's observations show that for men the same rule holds good; the most favourable temperature is 30° R (= 99°·5 Fahr.).‡ It appears also from Kühne's experiments that the heat of the blood of the Vertebrata must not exceed 113° Fahr., for at that temperature the myosin begins to coagulate. (Ludwig, *Lehrb. der Phys.*, band ii. p. 732.)§ Perhaps this fact may be connected with the pathological indication that a very high temperature in any disease (over 110° Fahr.) indicates the extremest danger.

To what temperature is the skin of the head and neck raised in the tropics in the sun's rays? No sufficient experiments have, I believe, been made, either on this point or on the heat in the interior of caps and hats with and without ventilation. Doubtless, without ventilation, the heat above the head in the interior of the cap is very great. It is quite possible, as usually assumed, that with bad head dresses the heat of the skin, bones, and possibly even of the deep nerves and centres (the brain and cord), may be greater than is accordant with perfect preservation of the currents of the nerves, or of the necessary temperature of the blood, or with the proper fluidity of some of the albuminous bodies in the muscles, or nerves.

The difficulty of estimating the exact effect of the solar rays is not onl caused by the absence of a sufficient number of experiments, but by the common presence of other conditions, such as a hot, rarefied, and perhaps impure air, and heat of the body produced by exercise, which is not attended by perspiration. Two points are remarkable in the history of sunstroke, viz., the extreme rarity of sunstroke in mid ocean,* and at great elevations.† In both cases the effect of the sun's rays, *per se*, is not less, is even greater, than on land and at sea-level; yet in both sunstroke is uncommon; the temperature of the air, however, is never excessive in either case.

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* In India the mortality of Eurasians (that is, the mixed race of British, Portuguese, Hindoo, Malay, blood mixed in all degrees) appears to be below that of the most healthy European service, viz., the Civil Service. Mr Tait's facts (On the Mortality of Eurasians; Statistical Journal, September 1864) would show that this mixed race will maintain itself in India.

† Eckhard, Henle's Zeitsch. band x. p. 165, 1851.

‡ Weber, Ludwig's Phys., 2d ed. vol. i. p. 128.

§ For a collection of data, see Dr H. C. Wood, jun., Thermic Fever, 1872, p. 50.

The effect of the direct rays on the skin is another matter requiring investigation. Does it aid or check perspiration? That the skin gets dry there is no doubt, but this may be merely from rapid evaporation. But if the nervous currents are interfered with, the vessels and the amount of secretion are sure to be affected, and on the whole it seems probable that a physiological effect adverse to perspiration is produced by the direct rays of the sun. If so, and if this is carried to a certain point, the heat of the body must rise, and supposing the same conditions to continue (intense radiant heat and want of perspiration), may pass beyond the limit of the temperature of possible life (113° Fahr.)‡

The effect of intense radiant heat on the respiration and heart is another point of great moment which needs investigation.

The pathological effect produced by the too intense direct rays of the sun is seen in one or two forms of insolation, and consists in paralysis of the heart or the respiration (see PREVENTION OF DISEASE).

A form of fever (the *Causus* of some writers, or thermic fever) has been supposed to be caused by the direct rays of the sun combined with excessive exertion. I have seen a case of this kind which corresponded closely to the description in books. The fever lasted for several days, and its type was not in accordance with the hypothesis that it was malarious fever, or febricula, or typhoid. No thermometric observations were made on the patient.

(*b*) *Heat in Shade.*—The effect of high air temperature on the native of a temperate climate passing into the tropics has not been very well determined, and some of the conclusions are drawn from experiments on animals exposed to an artificial temperature.

1. The temperature of the body does not rise greatly—not more than ·5 or 1° Fahr. (John Davy); from 1° to 2½° and 3° (Eydaux and Brown Séquard). In some experiments not yet published, Dr Becher determined his own temperature in a very careful way during a voyage round the Cape to India. He found the body-heat increased, and in the proportion of 0°·05 Fahr. for every increase of 1° Fahr. in the air. Rattray also found a decided increase, varying from 0°·2 Fahr. to 1°·2 Fahr.; the greatest increase was in the afternoon. We may conclude that the tropical heat raises the temperature of the body of a new-comer, probably because the evaporation from the skin is not capable of counterbalancing the great additional external heat, but it is not yet known that in old residents the same fact holds good. The temperature of the body is the result of the opposing action of two factors—1*st*, of development of heat from the chemical changes of the food, and by the conversion of mechanical energy into heat, or by direct absorption from without; and, 2*d*, and opposed to this, of evaporation from the surface of the body, which

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* The cases of isolation in a narrow sea like the Red Sea do not invalidate this rule.

† This may be due to the absence of radiation from the ground; ground radiation affects unprotected thermometers very markedly (F. de C).

‡ In the Turkish bath it may sometimes be observed, that on entering the hottest chamber the skin, which had previously been acting freely, becomes dry. A feeling of oppression accompanies this, but relief is experienced so soon as perspiration is re-established. This would seem to point more to an actual arrest of function than to a mere drying up of the secretion. The same thing in a modified degree may occur in a tropical climate, in which case the intensity of fever will depend upon the time that elapses before accommodation is reached.

regulates internal heat. So beautifully is this balance preserved, that the stability of the animal temperature in all countries has always been a subject of marvel. If anything, however, prevents this evaporation, radiation and the cooling effect of moving wind cannot cool the body sufficiently in the tropics. Then, no doubt, the temperature of the body rises, especially if in addition there is muscular exertion and production of heat from that cause. The extreme discomfort always attending abnormal heat of body then commences. In experiments in ovens, Blagden and Fordyce bore a temperature of 260° with a small rise of temperature (2½° Fahr.), but the air was dry, and the heat of their bodies was reduced by perspiration; when the air in ovens is very moist and evaporation is hindered, the temperature of the body rises rapidly.[*]

2. The respirations are lessened in number (Vierordt, Ludwig) in animals subjected to heat. According to Vierordt, less carbonic acid and presumably less water are eliminated. Rattray[†] has proved by a great number of observations that the number of respirations is lessened in persons passing from a cold to a hot climate. The amount of diminution varies; in some experiments the fall was from 16·5 respirations per minute in England, in winter, to 12·74 and 13·74 in the tropics. In another series of experiments the fall was from 17·3 respirations per minute to 16·1; the breathing is also gentler, *i.e.*, less deep. Rattray has also shown that the spirometric measurement of the expired air ("vital capacity of Hutchinson") increases in the tropics and falls in temperate climates, the average variation being about 8·7 per cent. of the total spirometric measurement.[‡] This will hold good at all ages, but is less at either extreme of life, and is most marked in persons of largest frame and most full blooded. The explanation of this spirometric increase in the respiratory action of the lungs, as compared with the lessened number of inspirations, is to be found, according to Rattray, in a lessened proportion of blood and a large proportion of air in the lungs in the tropics, and this is borne out by a fact presently to be noted, of the lessened weight of the lungs in Europeans in the tropics.

The effect of the lessened number of respirations is (in spite of the spirometric increase) to reduce the total respiratory action considerably. Rattray has shown that the average amount is in the temperate zone

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[*] It rises even 7° to 8° Fahr. (Ludwig, Lehrb. der Phys., 2d edit. b. ii. p. 730.) Obernier's late observations are confirmatory (Der Hitzschlag, Bonn, 1867). Obernier confirms the pathology generally received in this country. From an observation of four cases of sunstroke, and from thirty-three experiments on animals exposed to artificial heat, he traces all the effects to the augmented temperature of the body, which cannot cool by evaporation from the surface and lungs as usual. He puts down as necessary conditions, a high external temperature, internal conditions, as of marching, running, which augment bodily heat, and the absence of water. He does not, however, deny that there may be also a direct alteration of the nervous tissue by the heat. He noticed in two cases in men some amount of urea in the blood, but he did not find this in animals. He distinguishes two forms of sunstroke: asthenic, where the elevation of the temperature of the body brings on early collapse; and sthenic, where the bodily temperature attains a great height, and then suddenly the attack comes on with more or less reaction. In the one case there is a pale face and a copious sweating and cold skin (this is the heat asphyxia of some authors); in the other there is the red face, the injected eyes, the sobbing, breathing, convulsions, delirium, &c. Dr H. C. Wood, jun., of Philadelphia (Thermic Fever or Sunstroke, 1872), also holds that the "efficient cause of sunstroke is the excess of temperature," and he adopts the view that the rigidity of the heart depends on coagulation of the muscle-plasma, which occurs at 115° Fahr., a degree of heat almost attained in sunstroke; and he considers the cases of sudden cardiac deaths in India may be owing to this coagulation of the cardiac myosin; also that the nerve centres are as perniciously affected by temperature as the muscles; that a mammal becomes comatose when the temperature of the brain rises to 106°, and dies at 113° Fahr. Death may occur rapidly, however, he thinks, from paralysis of the respiratory centres.

[†] On the effects of Change of Climate on the Human Economy, by A. Rattray, M.D., [illegible], R.N.—Proceedings of the Royal Society, Nos. 122-126, 139 (1869-72).

[‡] Proceedings of the Royal Society, No. 129, p. 2.

(tem. = 54° Fahr.), 239·91 cubic inches per minute, while in the tropics (= 82° Fahr.) only 195·69 cubic inches were inspired, so that there is a difference of 38·65 cubic feet in twenty-four hours, or 18·43 per cent. in favour of a temperate climate. If 10 ounces of carbon are expired in the temperate zone, only 8·157 ounces would be expired in the tropics. Is there then greater excretion of carbon from the skin, or, as used to be supposed, from the liver?

Dr Francis (Bengal Army) has lately observed that the lungs are lighter after death in Europeans in India than the European standard. I made a similar observation many years ago, and recorded it in a work on cholera,[*] but had not sufficient facts to enable me to be quite certain. If this statement be confirmed, it would show a diminished respiratory function, and would accord with Rattray's observations.

3. The heart's action has been usually stated to be quickened in the tropics, but Rattray's numerous observations show that this is incorrect; the average pulse in the tropics was lower by 2½ beats per minute than in the temperate zone. In experiments on animals, moderate heat does not quicken the heart, but great heat does.

4. The digestive powers are somewhat lessened, there is less appetite, less desire for animal food, and more wish for cool fruit. The quantity of bile secreted by the liver is not increased, if the stools are to be taken as a guide (Marshall, in 1819, John Davy, Morehead, author), though Lawson believes that an excess of colouring matter passes out with the stools; nothing is known of the condition of the usual liver work.

5. The skin acts much more than usual (an increase of 24 per cent. according to Rattray), and great local hyperæmia and swelling of the papillæ occur in new comers, giving rise to the familiar eruption known as "prickly heat." In process of time, if exposed to great heat, the skin suffers apparently in its structure, becoming of a slight yellowish colour from, probably, pigmentary deposits in the deep layers of the cuticle.

6. The urine is lessened in quantity. The urea is lessened, as shown by experiments in hot seasons at home and during voyages (Dr Forbes Watson and Dr Becher).[†] It is probable that this is simply from lessened food. The pigment has been supposed to be increased (Lawson), but this is doubtful. The chloride of sodium is lessened; the amount of uric and phosphoric acids is uncertain.

7. The effect on the nervous system is generally considered as depressing and exhausting, *i.e.*, there is less general vigour of mind and body. But it is undoubted that the greatest exertions both of mind and body have been made by Europeans in hot climates. Robert Jackson thought as much work could be got of men in hot as in temperate climates. It is probable that the depressing effects of heat are most felt when it is combined with great humidity of the atmosphere, so that evaporation from the skin, and consequent lessening of bodily heat, is partly or totally arrested.[‡]

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[*] On Algide Cholera, by E. A. Parkes, M.D., p. 14 (1847).

[†] These experiments are not yet fully published; they were made during voyages to Bombay and China, and show that when the temperature reached a certain point (75° in Dr Becher's experiments), the solids of the urine and the urea lessened considerably.—*Proceedings of the Royal Society*, 1862.

[‡] See Dr Kenneth Mackinnon's Treatise on Public Health, p. 27, on the effect of plenty of exercise even in the hot, and moist, and presumed unhealthy climate of Tirhoot in Bengal. He proves that men can be much in the open air, even in the hot parts of the day, with impunity, and that when "they take exercise they are in the highest state of health." Is not the effect of great exercise beneficial in increasing the action of the lungs and heart, and [illegible] so far counteracting the effect of climate? Still Dr Mackinnon believes the climate is exhausting.

The most exhausting effects of heat are felt when the heat is continuous, *i.e.*, very great, day and night, and especially on sandy plains where the air is highly rarefied day and night. There is then really lessened quantity of oxygen in a given cubic space.* Add to this fact that the respirations are lessened, and we have two factors at work which must diminish the ingress of oxygen, and thereby lessen one of the great agents of metamorphosis.

8. Rattray has made observations† on the weight and height of forty-eight naval cadets, aged from 14½ to 17 years, during four successive changes of climate during a voyage. The results show that in the tropics they increased in height more rapidly than in cold climates, but that they lost weight very considerably, and, in spite of their rapid growth, Rattray concludes that the heat impaired the strength, weight, and health of these lads. His figures seem conclusive on these points, and show the beneficial influence of cold on youths belonging to races long resident in temperate climates.

On the whole, even when sufficient perspiration keeps the body temperature within the limits of health, the effect of great heat in shade seems to be, as far as we can judge, a depressing influence lessening the nervous activity, the great functions of digestion, respiration, sanguification, and directly or indirectly the formation and destruction of tissues. Whether this is the heat alone, or heat and lessened oxygen, and great humidity, is not certain.

So bad have been the general and personal hygienic conditions of Europeans in India, that it is impossible to say what amount of the great mortality in that country is due to excess of heat over the temperature of Europe. Nor is it possible to determine the influence of heat alone on the endemic diseases of Europeans in the tropics—liver disease and dysentery. There is, perhaps, after all, little immediate connection between heat and liver disease.

*Rapid Changes of Temperature.*—The exact physiological effects have not yet been traced out; and these sudden vicissitudes are often met by altered clothing, or other means of varying the temperature of the body. The greatest influence of rapid changes of temperature appears to occur when the state of the body in some way coincides with or favours their action. Thus, the sudden checking of the profuse perspiration by a cold wind produces catarrhs, inflammations, and neuralgia. I have been astonished, however, to find how well even phthisical persons will bear great changes of temperature, if they are not exposed to moving currents of air; and there can be little doubt that the wonderful balance of the system is soon readjusted.

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* A cubic foot of dry air at 32° weighs 566·850 grains, and if the proportion of nitrogen and oxygen be assumed to be by weight 67 and 23 per cent., and the slight amount of carbonic acid be neglected, there will be in a cubic foot—

436·475 grains of nitrogen.
130·375 „ oxygen.
566·850

As a man draws, on an average, when tranquil, 16·6 cubic feet per hour into his lungs, he will thus receive 130·375 × 16·6 = 2164·2 grains of oxygen per hour.

At a temperature of 80° the foot of air weighs 516·38 grains, and is made up by weight of—

397·61 grains of nitrogen.
118·77 „ oxygen.
516·38

Therefore, in an hour if a man withdraws 16·6 cubic feet, he will receive 118·77 × 16·6 = 1971·6 grains of oxygen per hour. Or, in other words, in an hour he would receive 192·6 grains of oxygen less with the higher temperature, an amount equal to about 9 per cent. of the amount supplied at the lower temperature.

If saturated with moisture, a cubic foot of air will contain 130 grains of oxygen at 32° and 112 grains at 100°.

† Proceedings of the Royal Society, No. 139.

## SECTION II.

## HUMIDITY.

According to their degree of humidity climates are divided into moist and dry. Professor Tyndall's observations have shown how greatly the humidity of the air influences climate, by hindering the passage of heat from the earth. As far as the body is concerned, the chief effect of moist air is exerted on the evaporation from the skin and lungs, and therefore the degree of dryness or moisture of an atmosphere should be expressed in terms of the relative (and not of the absolute) humidity, and should always be taken in connection with the temperature, movement, and density of the air, if this latter varies much from that of sea-level. The evaporating power of an atmosphere which contains 75 per cent. of saturation is very different, according as the temperature of the air is 40° or 80°. As the temperature rises, the evaporative power increases faster than the rise in the thermometer.

There is a general opinion that an atmosphere which permits free, without excessive, evaporation is the best; but there are few precise experiments.

The most agreeable amount of humidity to most healthy people is when the relative humidity is between 70 to 80 per cent. In chronic lung diseases, however, a very moist air is generally most agreeable, and allays cough. The evaporation from the lungs produced by a dry atmosphere appears to irritate them.

The moist hot siroccos, which are almost saturated with water, are felt as oppressive by man and beast; and this can hardly be from any other cause than the check to evaporation, and the consequent rise in the temperature of the body.

It is not yet known what rate of evaporation is the most healthy. Excessive evaporation, such as may be produced by a dry sirocco, is well borne by some persons, but not by all. Probably, in some cases, the physiological factor of perspiration comes into play, and the nerves and vessels of the skin are altered; and in this way perspiration is checked. We can hardly account, in any other way, for the fact, that in some persons, the dry sirocco, or dry hot land wind, produces harshness and dryness of the skin, and general malaise, which possibly (though there is yet no thermometric proof) may be caused by a rise of temperature of the body.

From the experiments of Lehmann on pigeons and rabbits, it appears that more carbonic acid is exhaled from the lungs in a very moist than in a dry atmosphere. The pathological effects of humidity are intimately connected with the temperature. Warmth and great humidity are borne, on the whole, more easily than cold and great humidity. Yet, in both cases, so wonderful is the power of adaptation of the body, that often no harm results.

The spread of certain diseases is supposed to be intimately related to humidity of the air. Malarious diseases, it is said, never attain their fullest epidemic spread unless the humidity approaches saturation. Plague and smallpox are both checked by a very dry atmosphere. The cessation of bubo plague in Upper Egypt, after St John's Day, has been considered to be more owing to the dryness than to the heat of the air.

In the dry Harmattan wind, on the west coast of Africa, smallpox cannot be inoculated; and it is well known with what difficulty cowpox is kept up in very dry seasons in India. Yellow fever, on the other hand, seems independent of moisture, or will at any rate prevail in a dry air. The observations at Lisbon, which Lyons has recorded, show no relation to the dew-point.

With regard to other diseases, and especially to diseases of sanguification and nutrition, observations are much needed.

## SECTION III.

### MOVEMENT OF AIR.

This is a very important climatic condition. The effect on the body is twofold. A cold wind abstracts heat, and in proportion to its velocity; a hot wind carries away little heat by direct abstraction, but, if dry, increases evaporation, and in that way may in part counteract its own heating power. Both, probably, act on the structure of the nerves of the skin, and on the contractility of the cutaneous vessels, and may thus influence the rate of evaporation, and possibly affect also other organs.

The amount of the cooling effect of moving bodies of air is not easy to determine, as it depends on three factors, viz., the velocity of movement, the temperature, and the humidity of the air. The effect of movement is very great. In a still atmosphere an extremely warm temperature is borne without difficulty. In the Arctic expeditions still air many degrees below zero of Fahr. caused no discomfort. But any movement of such cold air at once chills the frame. It has been asserted that some of the hot and very dry desert winds will, in spite of their warmth, chill the body; and if so, it can scarcely be from any other reason than the enormous evaporation they cause from the skin. It is very desirable, however, that this observation should be repeated, with careful thermometrical observations on the body and surface.

## SECTION IV.

### WEIGHT OF THE AIR.

I shall not here enter into the question, whether the slight changes in the pressure of the atmosphere, which occur at any one spot, have any effect on health, or any influence on disease.

#### *Effects of Considerable Lessening of Pressure.*

When the differences of pressure between two places is considerable, a marked effect is produced, and there seems no doubt that the influence of mountain localities is destined to be of great importance in therapeutics. It is of peculiar interest to the army surgeon, as so many regiments in the tropics are, or will be, quartered at considerable elevations.

In ascending mountains there is rarefaction, *i.e.*, lessened pressure of air; on an average (if the weight of the air at sea-level is 14 ℔ on every square inch) an ascent of 900 feet takes off ½ ℔; but this varies with height (see MEASUREMENT OF HEIGHTS); there are also lowered temperature, and lessened moisture above 4000 feet, greater movement of the air, increased amount of light, greater sun radiation, if clouds are absent. The air is freer from germs of infusoria. Owing to the rarefaction of the air and lessened watery vapour, there is greater diathermancy of the air; the soil is rapidly heated, but radiates also fast, as the heat is not so much held back by vapour in the air, hence there is very great cooling of the ground and the air close to it at night.

The physiological effects of lessened pressure begin to be perceptible at 2800 or 3000 feet of altitude (= descent of 2½ to 3 inches of mercury); they are quickened pulse* (fifteen to twenty beats per minute); quickened respiration (increase = ten to fifteen respirations per minute), with lessened spirometric capacity,* increased evaporation from skin and lungs; lessened urinary water.† At great heights there is increased pressure of the gases in the body against the containing parts; swelling of superficial vessels, and occasionally bleeding from the nose or lungs. A sensation of weight is felt in the limbs from the lessened pressure on the joints. At altitudes under 6000 or 7000 feet the effect of mountain air (which is, perhaps, not owing solely to lessened pressure, but also, possibly, to increased light and pleasurable excitement of the senses) is to cause a very marked improvement in digestion, sanguification, and in nervous and muscular vigour.‡ It is inferred that tissue change is accelerated, but nothing definite is known.

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* *Balloon ascents.*—Biot and Gay-Lussac at 9,000 feet = increase of 18 to 30 beats of the pulse.
Glaisher, . . . at 17,000 " = " 10 to 24 "
" . . at 24,000 " = " 24 to 31 "

The rapid evaporation at elevated positions is certainly a most important element of mountain hygiene. At Puebla and at Mexico the hygrometer of Saussure will often mark 37°, which is equal to only 45 per cent. of saturation (Jourdanet, "Du Mexique," p. 49), and yet the lower rooms of the houses are very humid, so that, in the town of Mexico, there are really two climates,—one very moist, in the rez-de-chaussée of the houses; one very dry, in the upper rooms and the outside air.

The diminution of oxygen, in a certain cubic space, is precisely as the pressure, and can be calculated for any height, if the barometer is noted. Taking dry air only, a cubic foot of air at 30 inches, and at 32° Fahr., contains 130·4 grains of oxygen. An ascent (about 5000 feet) which reduces the barometer to 25 inches will lessen this ⅙th, or $\left(\frac{25 \times 130{\cdot}4}{30} = \right)$ 108·6 grains. But it is supposed that the increased number of respirations compensate, or more so, for this; and, in addition, it must be remembered that in experiments on animals, as long as the percentage of oxygen did not sink below a certain point (14 per cent.), as much was absorbed into the blood as when the oxygen was in normal proportion. Jourdanet has indeed asserted ("Du Mexique," p. 76) that the usual notion that the respirations are augmented in number in the inhabitants of high lands is "completely erroneous;" that the respirations are in fact lessened, and that from time to time a deeper respiration is voluntarily made as a partial compensation. But Coindet, from 1500 observations on French and Mexicans, does not confirm this; the mean number of respirations was 19·36 per minute for the French, and 20·297 for the Mexicans.

As a curative agent, mountain air (that is, the consequences of lessened pressure chiefly) ranks very high in all anæmic affections from whatever cause (malaria, hæmorrhage, digestive feebleness, even lead and mercury poisoning); and it would appear, from Hermann Weber's observations, that the existence of valvular heart disease is, if proper rules are observed, no contra-indication against the lower elevations (2000 to 3000 feet). Neuralgia, gout, and rheumatism are all benefited by high Alpine positions (H. Weber). Scrofula and consumption have been long known to be rare among the dwellers on high lands, and the curative effect on these diseases of such places is also marked; but it is possible that the open air life which is led has an

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The beats seem to augment in number with the elevation. These are safer numbers than those obtained in mountain ascents, as there is no physical exertion. In mountain climbing the increase is much greater

[*] Rattray found an ascent of 2000 feet (at Ascension) lessened the "vital capacity," as judged of by the spirometer, from 266 to 249 and 243 cubic inches.

[†] Vivenot, Virchow's Archiv, 1860, band xix. p. 492. This is probable, but not yet proved.

[‡] Hermann Weber, Climate of the Swiss Alps, 1864, p. 17.

influence, as it is now known that great elevation is not necessary for the cure of phthisis.*

Dr Hermann Weber, in his important work on the Swiss Alps (p. 22), has given the present evidence, and has shown how in the true Alpine region—in Dauphiné, in Peru and Mexico, and in Germany—phthisis is decidedly averted or prevented by high altitudes.

Although on the Alps phthisis is arrested in strangers, in many places the Swiss women on the lower heights suffer greatly from it; the cause is a social one; the women employed in making embroidery congregate all day in small, ill-ventilated, low rooms, where they are often obliged to be in a constrained position; their food is poor in quality. Scrofula is very common. The men who live an open air life are exempt; therefore, in the very place where strangers are getting well of phthisis the natives die from it—another instance that we must look to local conditions and social habits for the great cause of phthisis. It would even seem possible that, after all, it is not indeed elevation and rarefaction of air, but simply plenty of fresh air and exercise, which are the great agents in the cure of phthisis.

Jourdanet, who differs from so much that is commonly accepted on this point, gives additional evidence on the effect of elevation on phthisis. At Vera Cruz phthisis is common; at Puebla and on the Mexican heights, it is almost absent (à peu près nulle).

The diseases for which mountain air is least useful are—rheumatism, at the lower elevations where the air is moist; above this rheumatism is improved; and chronic inflammatory affections of the respiratory organs (?). The "mountain asthma" appears, however, from Weber's observations, to be no specific disease, but to be common pulmonary emphysema following chronic bronchitis.

It seems likely that pneumonia, pleurisy, and acute bronchitis, are more common in higher Alpine regions than lower down.

*Effects of increased Pressure.*—The effects of increased pressure have been noticed in persons working in diving-bells, &c., or in those submitted to treatment by compressed air. (At Lyons and at Reichenhall † especially.) When the pressure is increased to from 1½ to 2 atmospheres, the pulse becomes slower, though this varies in individual cases; the mean lessening is 10 beats per minute; the respirations are slightly lessened (1 per minute); evaporation from the skin and lungs is said to be lessened (?); there is some recession of blood from the peripheral parts; there is a little ringing and sometimes pain in the ears; hearing is more acute; the urine is increased in quantity; appetite is increased; it is said men will work more vigorously. When the pressure is much greater (two or three atmospheres) the effects are sometimes very marked; great lowering of the pulse, heaviness, headache, and sometimes, it is said, deafness. It is said ‡ that more oxygen is absorbed, and that the venous blood is as red as the arterial; the skin also sometimes acts more, and there may even be sweating. The main effect is to lessen the quantity of blood in the veins and auricles, and to increase it in the arteries and ventricles; the filling of the ventricle during the relaxation takes place more slowly. The diastolic interval is lengthened, and the pulse is therefore slower.

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* Some time ago a remarkable paper was published by Dr James Blake of California on the treatment of phthisis (Pacific Medical Journal, 1860). He adopted the plan of making his patients live in the open air; in the summer months he made them sleep out without any tent: the result was an astonishing improvement in digestion and sanguification; the resistance to any ill effects from cold and wet is described as marvellous. As Dr Blake is well known to be perfectly trustworthy, these statements are worthy of all consideration.

† For an account of the effects noted at Reichenhall, see Dr Burdon Sanderson's account in The Practitioner, No. ix. 1868, p. 221.

‡ Foley. Du Travail dans l'air comprimé, Gaz. Hebdom., 1863, No. 32.

When the workmen leave the compressed air they are said to suffer from hæmorrhages and occasional nervous affections, which may be from cerebral or spinal hæmorrhage.* As a curative agent in phthisis, the evidence is unfavourable.

Some observations lately made by M. Bert† show that oxygen, when it enters the blood under pressure (such as that given by 17 atmospheres of atmospheric air, or 3½ atmospheres of pure oxygen), is toxic to birds, producing convulsions. Convulsions are produced in dogs when the pressure is only 7 or 8 atmospheres, and when the oxygen amounts to only double the normal amount, or, in other words, reaches 32 C.C. per 100 C.C. of blood. M. Bert conjectures that the toxic influence of oxygen is on the nervous centres, like strychnine. The animal temperature fell 2 or 3 degrees (C.) during the convulsions, so that excess of oxygen did not cause increased combustion. In the case of a dog kept under a pressure of 9½ atmospheres for some time, gas was found in the ventral cavity and in the areolar tissue. In man the pressure of only 5 atmospheres appears to be dangerous.‡

### *Is Acclimatisation possible ?*

The doctrine of acclimatisation has been much debated, but probably we do not know sufficiently the physiological conditions of the body under different circumstances. In the case of Europeans living till puberty in a temperate region, near the sea-level, and in a moist climate like England, and then going to the tropics, the question of acclimatisation would be put in this form,—Does the body accommodate itself to greater heat, to lessened humidity in some cases, or greater in others, and to varying altitudes ?

There can be little doubt that the body does accommodate itself within certain limits to greater heat, as we have seen that the lungs act less, the skin more, and that the circulation lessens when Englishmen pass into the tropics. There is so far an accommodation or alteration impressed on the functions of the body by unwonted heat. And we may believe that this effect is permanent, *i.e.*, that the lungs continue to act less, and the skin more, as long as the Europeans remain in the tropics. Doubtless, if the race were perpetuated in the tropics, succeeding generations would show fixed alterations in these organs.

We may conclude that the converse holds true, and that the cold of temperate regions will influence natives of the tropics in an opposite way, and this seems to be rendered likely by the way in which lung affections arise in many of them.

We may admit there is an acclimatisation in this sense, but in no other. The usual belief that the constitution acquires in some way a power of resisting unhealthy influences—that is, a power of not being any longer susceptible to them—is not supported, as far as I can see, by any evidence. The lungs in Europeans will not regain their weight and amount of action in the tropics; a change to a cold climate only will cause this; the skin retains its increased function until the cause producing it is removed. So also there is no acclimatisation in any sense of the word for malaria. It would seem desirable to discontinue the use of a term which has had several meanings, and to replace Acclimatisation by the word Accommodation.

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* See *Lissonsin* in Canstatt, 1863, band ii. p. 105, and Babington in Dublin Quarterly Journal, Nov. 1864.

† Chemical News, March 28, 1873.

‡ In the colliery accident at Pont-y-Prydd, several men were confined for ten days in a small space, in which the air was much compressed. The exact pressure is unknown, but it was sufficient to drive one of the men, with fatal force, into the opening made for their rescue. Although the men were without food all the time they appeared to have suffered less than might have been anticipated.

## SECTION V.

## COMPOSITION OF THE AIR.

The proportionate amounts of oxygen and nitrogen remain very constant in all countries, and the range of variation is not great.

So also, apart from the habitations of men, the amount of carbonic acid is (at elevations occupied by men) constant. The variations in watery vapour have been already noticed.

The only alterations in the composition of the air which come under the head of climate, are changes in the state in which oxygen exists (for no change is known to occur in nitrogen), and the presence of impurities.

### SUB-SECTION I.—OZONE.

Ozone is now admitted by most chemists to be an allotropic condition of oxygen; and, as conjectured by Odling, it is now believed that it is a compound molecule made up of three molecules ($O_2O$) of oxygen. The so-called antozone is now believed to be peroxide of hydrogen diffused in a large quantity of atmospheric air. Variations in the amount of ozone have been supposed to be a cause of climatic difference, but, in spite of all the labour which has been given to this subject, the evidence is very unconclusive. The reaction with the ozone paper is liable to great fallacies* (see METEOROLOGY). Yet it seems clear that some points are made out; the ozonic reaction is greater in pure than impure air; greater at the sea-side than in the interior; greater in mountain air than in the plains; absent in the centre of large towns, yet present in the suburbs; absent in an hospital ward, yet present in the air outside. In this country it is greater with south and west winds; greater, according to Moffat, when the mean daily temperature and the dew-point temperature are above the mean; the same observer found it in increased quantity with decreasing readings of the barometer, and conversely in lessened quantity with increasing readings.

The imperfections in the test render it desirable to avoid drawing conclusions at present; but one or two points must be adverted to.

1. Owing probably to the oxidising power of ozone when prepared in the laboratory, a great power of destruction of organic matter floating in the air has been ascribed to ozone by Schönbein, and the absence of ozone in the air has been attributed by others to the amount of organic matter in the air of towns. Even the cessation of epidemics (of cholera, malarious fevers) has been ascribed to currents of air bringing ozone with them. The accumula-

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* The subject of ozone will be found fully discussed by Dr C. Fox (Ozone and Antozone, 1873). The causes of fallacy in the tests are carefully explained. Admitting the uncertainties of the subject, and doubting whether ozone has been shown to play any part in aiding or averting epidemic diseases, Dr Fox yet concludes that ozone is an agent of great importance in nature; that it decomposes some of the offensive products of putrefaction; and, as it exists naturally in the air, we may infer that the consumption or non-existence of ozone may contribute to the formation of an unhealthy atmosphere (p. 168). Dr Fox adopts the view that ozone is made up of three atoms of oxygen, and that its formula is $O_2O = 48$. Antozone he considers to be peroxide of hydrogen the mixing of which with ozone would cause the following change:

$$O_2O + H_2O_2 = H_2O + 2O_2$$

One molecule of water and two of oxygen, in the form in which we are acquainted with it in a separate state.

tion of malaria at night has been ascribed to the non-production of ozone by the sun's rays (Uhle.) The effect of stagnant air in increasing epidemics has also been ascribed to the absence of ozone.

It seems clear that the substance giving the reaction of ozone is neither deficient in marshy districts, nor when ozone is conducted through marsh dew does it destroy the organic matter.* Is there any experimental proof that it acts on the organic impurities of respiration? I have been able to find none recorded, except the fact already noticed, that the reaction is least in impure air.

2. On account of the irritating effect of ozone, when rising from an electrode, Schönbein believed it had the power of causing catarrh, and inferred that epidemics of influenza might be produced by it. He attempted to adduce evidence, but at present it may safely be said that there is no proof of such an origin of epidemic catarrhs.

3. A popular opinion is, that a climate in which there is much ozone (*i.e.*, of the substance giving the reaction with iodide and starch paper) is a healthy, and, to use a common phrase, an exciting one. The coincidence of excess of this reaction with pure air lends some support to this, but, like the former opinions, it still wants a sufficient experimental basis.

On the whole, the subject of the presence and effects of ozone, curious and interesting as it is, is very uncertain at present; experiments must be numerous, and inferences drawn from them must be received with caution.

## SUB-SECTION II.—MALARIA.

The most important organic impurity of the atmosphere is malaria (for Air of Marshes, see page 111), and when a climate is called "unhealthy," in many cases it is simply meant that it is malarious. In the chapters on SOILS and AIR the most important hygienic facts connected with malaria have been noted. In this place it only remains to note one or two of the climatic points associated with malaria.

1. *Vertical Ascent.*—A marsh or malarious tract of country existing at any point, what altitude gives immunity from the malaria, supposing there is no drifting up ravines? It is well known that even a slight elevation lessens danger—a few feet even, in many cases, but complete security is only obtained at greater heights. Low elevations of 200 to 300 feet are often, indeed, more malarious than lower lands, as if the malaria chiefly floated up.

At present the elevation of perfect security in different parts of the world is not certainly determined, but appears to be—

| | |
|---|---|
| Italy, . . . . | 400 to 500 feet.† |
| America (Appalachia), . . | 3000 ,, |
| California,‡ . . . . | 1000 ,, |
| India, . . . . | 2000 to 3000 ,, |
| West Indies, . . | 1400 ,, 1800 up to 2200 feet. |

But these numbers are so far uncertain that it has not always been seen that the question is not, whether marshes can exist at these elevations (we know they can be active at 6000 feet), but whether the emanations from a marsh will ascend that height without drifting up ravines? I cannot help suspecting that 1000 to 1200 feet would generally give security.

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* In addition to what has been previously said (p. 112), Grellois has lately stated that he found more ozone over a marsh than elsewhere. An interesting series of observations on ozone in the Bombay Presidency has been made by Dr Cook, and, if continued, will probably give us some reliable data in a few years.

† Carrière, quoted by Levy, t. i. p. 491.

‡ This information was given me by my friend Dr James Blake.

2. *Horizontal Spread.*—In a calm air Levy[*] has supposed that the malaria will spread until it occupies a cube of 1400 to 2000 feet, which is equivalent to saying it will spread 700 to 1000 feet horizontally from the central point of the marsh. But currents of air take it great distances, though the best observations show that these distances are less than were supposed, and seldom overpass one or two miles, unless the air-currents are rapid and strong. The precise limits are unknown, but it is very doubtful if the belief in transference of malaria by air-currents for 10, 20, or even 100 miles, is correct.

3. *Spread over Water.*—The few precise observations show that this differs in different countries. In the Channel, between Beveland and Walcheren, 3000 feet of water stopped it (Blane). In China and the West Indies a farther distance is necessary. In China three-quarters of a mile has been effectual;[†] in the West Indies one mile. Grant thinks salt water more efficacious than fresh.

## SECTION VI.

## ELECTRICAL CONDITION—LIGHT.

That these, as well as heat, are important parts of that complex agency we call Climate, seems clear; but little can be said on the point. In hot countries positive electricity is more abundant; but the effect of its amount and variation on health and on the spread and intensity of diseases is quite unknown. All that has been ascribed to it is pure speculation. The only certain fact seems to me that the spread of cholera is not influenced by it.

With regard to light, the physiological doctrine of the necessity of light for growth and perfect nutrition makes us feel sure that this is an important part of climate, but no positive facts are known.

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[*] T. i. p. 464.

[†] Grant (quoted by Chevers), Indian Annals, 1859, p. 636.

# CHAPTER XV.

## DESCRIPTION OF THE METEOROLOGICAL INSTRUMENTS, AND A FEW REMARKS ON METEOROLOGY.

As meteorological observations are now so commonly made, and as in the army instruments are provided at many stations, it is desirable to give a few plain instructions on the use of these instruments.* For the convenience of beginners, also, I have made a few observations on Meteorology.

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* The following is the official circular issued by the Army Department:—

*Official Instructions for Reading the Meteorological Instruments.*

The observer should make himself thoroughly acquainted with the scale of every instrument, especially with that of the barometer and its attached vernier, and by frequent comparisons ascertain that he and his deputy read the instruments alike, and record the observations accurately.

All observations must be recorded exactly as read. The corrections are to be made only at the end of each month on the "means" of the "sums."

Barometrical observations must be recorded to the third decimal place; thermometrical to the first decimal. When the readings are exactly to the inch or degree, the places for the decimals must be filled up with ciphers.

The observations should be made as quickly as possible, consistent with perfect accuracy, and the observer must avoid breathing on the instruments, particularly the dry and wet bulb, and maximum thermometers.

*Barometer Readings.*—Note the temperature of attached thermometers in degrees only; by means of the thumb-screw at the bottom adjust the mercury in the cistern to its proper level, the point of the ivory cone, which should just touch the mercury without breaking the surface; then bring the zero line of the vernier to the level of the apex of column of the mercury, and read off in the manner described at pages 15 and 16 of Sir H. James's Book of Instructions.*

*Thermometer Readings.*—The scales are divided to degrees only, but these are so open that the readings can be determined to the tenth of a degree. Practice and attention will insure accuracy.

*Maximum Thermometer in Shade.*—The maximum thermometer must be hung at such a distance (2 or 3 inches) from the water vessel of the wet-bulb thermometer, that its readings may not be affected by evaporation.

In hanging the maximum, care must be taken that the end of the tube is *slightly inclined downwards*, which will have the effect of assisting in preventing the return of any portion of the column of mercury into the bulb on a decrease of temperature. To read the instrument, gently elevate the end furthest from the bulb to an angle of about 45°, in which position of the instrument note the reading. To reset the thermometer, a gentle shake or swing, or a tap on the wooden frame of the instrument, will cause the excess of mercury to return to the bulb, and it is again ready for use.

*Maximum in Sun's Ray's, or the Vacuum Solar Radiation Thermometer.*—Being constructed on the same principle as the last mentioned instrument, it must be read in a similar position. After completing the reading, by giving the instrument a slight shake, with the bulb still inclined downwards, the excess of mercury will return to the bulb, and the thermometer be ready for the next observation.

*Minimum Thermometer in Shade.*—The minimum thermometer must be so hung that the bulb may be about *one inch lower* than the other extremity of the instrument, because in this position the index is less likely to be affected by a rise in temperature.

The extremity of the index furthest from the bulb shows the lowest degree to which the spirit has fallen since the last observation. The reading on the scale corresponding to this is the temperature to be recorded. Then, by elevating the bulb, the index will float towards the end of the spirit. When it has *nearly arrived at that point*, the instrument is re-set.

*Minimum on Grass, Terrestrial Radiation Thermometer* is constructed like the last, and the directions above given are also applicable to it.

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* For these are now substituted "Instructions in the use of Meteorological Instruments," by R. H. Scott, M.A., F.R.S., 1875. The Barometer corrections are explained at pp. 14, 21.

## SECTION I.

## THERMOMETERS FOR TAKING THE TEMPERATURE OF THE AIR.

### *Maximum Thermometers.*

Two maximum thermometers are issued—one to observe the greatest heat in the sun, the other in the shade.

The *Sun Maximum or "Solar Radiation Thermometer"* is formed by a glass case (from which the air is removed), containing a mercurial thermometer with a blackened bulb. The case shelters from currents of air; the black bulb absorbs the sun's rays. The tube of the thermometer is slightly bent near the bulb, and a piece of porcelain is inserted which narrows the tube. The effect of this is to make the thermometer self-registering, as, after the mercury has expanded to its fullest extent, instead of retiring into the bulb on cooling, it is stopped by the porcelain, and the mercury breaks between the porcelain and the bulb. The instrument is placed at a height of four feet from the ground on wooden supports, and in any place where the sun's rays can freely fall on it.

The *Shade Maximum* is a mercurial thermometer, not inclosed in a case but mounted on a frame. Its construction and manner of reading are otherwise similar to those of the sun thermometer.

It is placed in the shade four feet above the ground, and sufficiently far from any walls to be unaffected by radiation. It should be freely exposed to air, but perfectly protected from the sun's rays.

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After reading and re-setting the self-registering thermometers, comparethem with the dry-bulb thermometer in order to ascertain that their readings are nearly the same.

*Dry and Wet-Bulb Thermometers.*—Bring the eye on a level with the top of the mercury in the tube of the dry-bulb thermometer, and take the reading, then complete the observation by noting in like manner the reading of the wet-bulb thermometer.

The temperature of the air is given by the former, that of evaporation by the latter. From these data the hygrometrical results are to be calculated by Glaisher's Tables, 3d edition.*

*Rain-Gauge and Measure.*—Pour the contents of the gauge into any convenient vessel with a lip, and from this into the glass measure, which has been graduated especially for the gauge, and is only to be used in measuring its contents. It is graduated to the hundredths of an inch.

*Anemometers*—The dials are read from left to right. The first on the left records hundreds of miles, the second tens, the third miles, the fourth tenths of a mile, and the fifth hundredths of a mile.

The reading of the anemometer is obtained by deducting from the amount registered by the dials the total sum registered at the period of the preceding observation. The difference between those (subject to a small correction) indicates the velocity or horizontal movement of the air in miles during the interval, and must be entered in the return. When the instrument is first set up, the reading on the dials must be noted, in order that it may be deducted from the total registered by the dials at the end of the first period of observation.

In making observations on the presence of ozone, a box has been found to be unnecessary, equally satisfactory results having been obtained by fixing the paper immediately under the penthouse of the stand, which shelters it sufficiently from a strong light, while it secures proper exposure.

The minimum thermometers are liable to get out of order—first, by carriage, when the index may be wholly or partly driven out of the spirit, or a portion of spirit may become detached from the main column; and, secondly, by slow evaporation of the spirit, which rising in the tube, condenses at the upper end. The first-mentioned errors are corrected by taking the thermometer in the hand, with its bulb downwards, and giving it a swing up and down. The second is remedied by the inclined position of the instrument, which allows the condensed spirit to trickle back to the main column.†

*N.B.*—On no account whatever is artificial heat to be applied to a spirit thermometer. In re-setting the minimum, the index should never be brought quite to the end of the column of spirit.

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* A 6th edition is now published.

† It is generally necessary to swing the instrument to get back the broken portion of the column.

### *Minimum Thermometers.*

Two minimum thermometers are supplied.

The *Shade Minimum* is an alcoholic thermometer with a small index in the alcohol. It is set by shaking the index *nearly* to the end of the spirit; as the spirit contracts during cold it carries the index down; when it expands again it cannot move the index, but leaves it at the degree of greatest cold. The end of the index farthest from the bulb is the point to read.

This thermometer is placed in the shade four feet above ground, under the same conditions as the former.

The *Grass Minimum* or "*Terrestrial Radiation Thermometer*" is a thermometer of the same kind, but protected by a glass shield. It is placed almost close to the ground on grass, suspended on little tripods of wood, but it should not touch the ground; it is intended to indicate the amount of cooling produced by radiation from the ground. If snow lies on the ground the bulb should be placed in the snow. Scott ("Instructions, &c.") recommends a black board on which to lay the thermometer, in preference to grass.*

### *Common Thermometer.*

The dry bulb of the "wet and dry bulb thermometer" is read as a common thermometer.

### *Reading of the Thermometers.*

All these thermometers can be read to tenths of a degree. The maximum and minimum thermometers are read once a day, usually at 9 A.M.; the former marks the highest point reached on the previous afternoon, and must be so entered on the return; the latter, the lowest point reached on the same morning.† For the army returns the common thermometer is read twice a day, at 9 A.M. and 3 P.M.

*Range of the Temperature.*—The maximum and minimum in shade give most important climate indcations; the difference between them on the same day constitutes the range of the diurnal fluctuation. The range is expressed in several ways.

The extreme daily range in the month or year is the difference between the maximum and minimum thermometer on any one day.

The extremely monthly or annual range is the difference between the greatest and least height in the mean of month or year, as compared with another.

The mean monthly range is the daily ranges added and divided by the number of days in a month.

The mean yearly range is the monthly ranges added and divided by 12.

*Mean Temperature.*—The mean temperature of the day is obtained in the following ways:—

(*a*) At Greenwich and other observatories, where by means of photography the height of the thermometer at every moment of the day is registered, the mean of the hourly readings is taken. This has been found to accord with the absolute mean (found by taking the mean of the whole curve) to within $\frac{1}{10}$th of a degree.

(*b*) Approximately in several ways. Taking the mean of the shade maximum and minimum of the same day. In this country, during the cold months (December and January), the result is very close to the truth; but as the temperature increases, a greater and greater error is produced, until in July the mean monthly error is +1°·9 Fahr., and in some hot days is much greater. In the tropics, the mean of the maximum and minimum must give a result still further from the truth.

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* Great difficulty is found with spirit thermometers on account of their being so much less sensitive than mercurial. To remedy this the bulb is sometimes made fork-shaped, or otherwise modified so as to expose as large a surface as possible.

† It would be desirable that the thermometer should be read both morning and evening. In winter the maximum sometimes occurs in the early morning and the minimum in the afternoon. In winter the range depends more on the wind than on the time of day (Scott).

Monthly corrections can be applied to bring these means nearer the truth. Mr Glaisher's correction for this country is as follows:—

Subtract from the monthly mean of the maximum and minimum—

| | | | | | |
|---|---|---|---|---|---|
| January, | 0°·2 | May, | 1°·7 | September, | 1°·3 |
| February, | 0·4 | June, | 1·8 | October, | 1·0 |
| March, | 1·0 | July, | 1·9 | November, | 0·4 |
| April, | 1·5 | August, | 1·7 | December, | 0·0 |

The result is the approximate mean temperature. But this is true only for this country.*

In a great number of places the mean temperature of the day and year, as stated in books, is derived solely from the mean of the maximum and minimum. According to Scott, the approximation to the true mean is very close in most parts of the world, especially if the observations be taken as near the *end* of the period as possible, near midnight, for instance, for the mean of the civil day of twenty-four hours.

The approximate mean temperature may also be obtained by taking observations at certain times during the day, and applying a correction. Mr Glaisher has given some very valuable tables of this kind,† which can be consulted.‡

If the temperature be taken twice a day, at homonymous hours, such as 9 A.M. and 9 P.M., the mean of these does not differ much from the true daily mean (Scott).

The nearest approach to the mean temperature of the day by a single observation is given at from 8 to 9 P.M.; the next is in the morning—about 8 o'clock in July and 10 in December and January.

The nearest approach to the mean annual temperature is given by the mean of the month of October. Observations made from a week before to a week after the 24th April, and again in the corresponding weeks of October, give a certain approximation to the yearly mean temperature (Herschel, "Meteorology," p. 180).

The changes in temperature of any place, during the day or year, are either periodic or non-periodic. The former are dependent on day and night, and on the seasons, *i.e.*, on the position of the place with respect to the sun. The

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* These numbers of Mr Glaisher are likely to be modified very considerably by the observations of the Astronomer-Royal, about to be published.

† On the Corrections to be applied to Meteorological Observations for Diurnal Range, prepared by the Council of the British Meteorological Society, 1850. These corrections are applicable only to this country.

‡ The following rules, which are applicable in all parts of the world, are given by Herschel:—*

If observations are taken three times daily—at 7 A.M., 2 P.M., and 9 P.M.,—hours which we may denote by $t$, $t'$, and $t''$; then

$$\frac{t+t'+2t''}{4} = \text{mean temperature of day.}$$

If the hours are 8 A.M., 3 P.M., and 10 P.M., the formula is—

$$\frac{7t+7t'+10t''}{24} = \text{mean of day.}$$

---

*Meteorology, p. [illegible]

periodic changes are sometimes termed fluctuations, and the differences between day and night temperatures, or the temperatures of the hottest and coldest months, are often called the amplitudes of the daily or yearly fluctuations.

The non-periodic changes are dependent chiefly on shifting winds, and may either augment or lessen the periodic changes. They are sometimes termed undulations. The thermometer makes, of course, no distinction between these two causes of change, but the observer should distinguish them if possible.

*Daily Periodic Changes.*—On land the temperature of the air is at its lowest about 3 o'clock A.M., or just before sunrise, and at its maximum about 2 o'clock P.M.; it then falls nearly regularly to 3 o'clock A.M. At sea, the maximum is nearly an hour later.

The amount of diurnal periodic change is greater on land than on water; in the interior of continents than by the sea-side; in elevated districts than at sea-level. As far as land is concerned, it is least on the sea-coast of tropical islands, as at Kingston in Jamaica, Colombo in Ceylon, Singapore, &c.

*Yearly Periodic Changes.*—In the northern hemisphere, the coldest month is usually January; in some parts of Canada it is February. On the sea, the coldest month is later, viz., March. The hottest month is in most places July, in some few August; on the sea it is always August. The coldest days in this country are towards the 21st January; the hottest, about the 18th to the 21st July. At Toronto the hottest day is 37 days after the summer solstice; and the coldest, 55 days after the winter solstice.

It is thus seen that both for the diurnal and annual alterations of heat the greatest heat is not simultaneous with, but is after, the culmination of the sun; this is owing to the slow absorption of heat by the earth.

The amplitude of the yearly fluctuation is greater on land than sea, and is augumented by land, so that it reaches its highest point in the interior of great extra-tropical continents.

It increases towards the pole for three reasons,—

1. The geographical fluctuation of the earth's position causes a great yearly difference of the angle with which the sun's rays fall on the earth.

2. The duration of incidence of the sun's rays (*i.e.*, the number of hours of sunshine or shade) have greater yearly differences than in the tropics.

3. In the northern hemisphere especially there is a very great extent of land, which increases radiation.

The amplitude of the yearly fluctuation is very small in the tropical lands at sea-level. At Singapore, it is only 3°·6 Fahr. (Jan. 78°·8, July 82°·4), while it is immense on continents near the pole. At Jakoutsk, in North Asia, it is 112°·5 (January − 44°·5 and July + 68°). All fluctuations depend to a large extent upon the distance from the sea, although local causes may have some influence, such as the vicinity of high lands.

In any place there may be great undulations and small fluctuations, or great changes in each way. At Brussels, the greatest possible yearly undulation is 90°. In some parts of Canada, immense undulations sometimes occur in a day, the thermometer ranging even 50° to 70° in one day.

The hot winds of the rainless deserts have long puzzled meteorologists; they often cause enormous undulations, 50° to as much as 78° Fahr.

### *Temperature of the Air of any place.*

This depends on the following conditions:—

1. *Geographical position as influencing the amount and duration of sun's rays which are received.*—The nearer the equator the hotter. For 23½° on

either side the equator the sun's rays are vertical at one period of the year, and are never more oblique than 47°. The mean yearly temperature of the equator is 82° Fahr.; of the pole about 2°·5 Fahr. The decline from the equator to the pole is not regular; it is more rapid from the equator to 30° than in the higher latitudes.

2. *Relative amount of Land and Water.*—The sun's rays passing through the air with but trifling loss fall on land or on water. The specific heat of land being only one quarter that of water, it both absorbs heat and gives it out more rapidly. Water, on the other hand, absorbs it more slowly, stores up a greater quantity, and parts with it less readily. The temperature of the superficial water, even in the hottest regions, seldom exceeds 80° to 82°, and that of the air is generally below (2° to even 6°) the temperature of the water (J. Davy). Consequently the more land the greater is the heat, and the wider the diurnal and yearly amplitudes of fluctuation. The kind of soil has a great effect on absorption, and the land also transmutes the heat to a certain extent (see SOIL). The evaporation from the water also greatly cools the air (see EVAPORATION).

3. *Elevation of the place above the Sea-level.*—The greater the elevation the colder the air, on account—1*st*, of the lessening amount of earth to absorb the sun's rays; and, 2*d*, on account of the greater radiation into free space. The decline of temperature used to be reckoned at about 1° Fahr. for each 300 feet of ascent, but the balloon ascents of Mr Welsh, and especially of Mr Glaisher, have proved that there is no regular decline; there are many currents of warm air even in the upper atmosphere. Still the old rule is useful as an approximation. The amount of decline varies, however, in the same place at different times of the year. In Mr Glaisher's balloon ascents, in a *cloudy* sky, it was about 4° Fahr. for each inch of barometric fall, at first; but when the barometer had fallen 11 inches, the decline of temperature was more rapid. Under a *clear* sky there was a fall of 5° Fahr. for each of the first four inches of descent; then 4° per inch till the thirteenth inch of descent, and then 4°·5 for fourteenth, fifteenth, and sixteenth inches of descent.

The snow-line at any spot, or the height at which snow will lie the whole year, can be approximately reckoned by taking the mean yearly temperature of the latitude at sea-level, and multiplying the difference between that temperature and 32° Fahr. by 300. The aspect of a place, however, and other circumstances, have much to do with the height of the permanent snow-line. The mean temperature of any place can be approximately reckoned in the same way, if the mean temperature of the latitude at sea-level, and the elevation of the place in feet, be known.

4. *Aspect and Exposure; and Special Local Conditions.*—These circumstances chiefly affect a place by allowing free exposure to, or sheltering from the sun's rays, therefore lessening the number of hours the rays reach the soil, or by furnishing at certain times a large moist surface. Thus the extensive sandbanks of the Mersey cause very rapid alterations of temperature in the water and air, by being exposed every twenty-four hours twice to the sun and sky (Adie).

5. *Aërial and Ocean Currents.*—These have a great effect, bringing clouds which block out the sun or produce rain, or which, in the case of ocean currents, cool or warm the air. The cold polar sea currents and the warm equatorial (like the Gulf Stream) in some cases almost determine, and always greatly influence, the temperature of a place.

6. *Nature of the Soil.*—On this point little is yet known, but it is certain that some soils easily absorb heat; others do not. The moist and clayey soils are cold; the dry hard rocks and dry sands are hot.

The hottest places on the earth are—in the eastern hemisphere, near the Red Sea, at Massava and Khartoum (15° N.L.), and on the Nile in Lower Nubia; annual temperature = 90°·5 Fahr.; in the western hemisphere, on the Continent, near the West Indies, the annual temperature is 81°·5. These are sometimes called the climatic poles of heat. The poles of cold are in Siberia (Jakoutsk to Ustjausk, 62° N.), and near Melville Island.

*Isothermal Lines.*—These are lines drawn on charts, and were proposed by Humboldt to connect all places having the same mean annual temperature. The various conditions just noted cause these lines to deviate more or less from the lines of latitude. The isothermal lines are now drawn to represent the places of the same mean monthly, or mean winter or summer temperature.

The lines of mean summer temperature (three months, June, July, August) are called isotheral; those of mean winter temperature (December, January, and February) are called isocheimonal.*

## SECTION II.

## HYGROMETERS—HUMIDITY OF THE AIR.

The amount of watery vapour in the air can be determined in several ways; by direct weighing, by Daniell's or Regnault's hygrometer, by the hair hygrometer of Saussure, and by the dry and wet bulbs.† The method by the dry and wet bulb thermometers has been adopted by the Army Medical Department, and observations are taken twice daily (9 A.M and 3 P.M.). The instruments are not self-registering, and are simply read off. They are placed in the shade, four feet above the ground, the bulbs freely exposed to the air, but not exposed to the effect of radiant heat from brick walls, &c. The wet bulb is covered with muslin, which is kept moistened by cotton twisted round the bulb and then passing into the water vessel; the cotton is soaked in solution of carbonate of soda, or boiled in ether to free it from fat, so that water may ascend easily in it by capillary attraction; the muslin and cotton should be renewed frequently, once or twice a month if possible; the water must be either rain or distilled water, and the supply ought to be more ample in dry hot weather than in damp. When the temperature is below the freezing-point, the passage of water along the syphon is arrested; it is then necessary to moisten the wet bulb, allow the moisture to freeze, and then sometime after to take the reading. The dew-point, the weight of a cubic foot of vapour, and the relative humidity, are then taken from Mr Glaisher's tables.‡

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* It may be well to mention the relations between the three principal thermometer scales. Whilst the freezing-point in the Fahrenheit scale is at 32° it is at 0° in both the Centigrade (or Celsius) and the Réaumur scales. Water boils at 212° on the Fahrenheit scale (barometer = 29·905), at 100° on the Centigrade, and at 80° of Réaumur.

Hence the formula of reduction is:—
from which the corresponding temperatures can easily be found,

$$\frac{F-32}{9} = \frac{C}{5} = \frac{R}{4},$$

† These are to be considered as one instrument, and are frequently called the Psychrometer of August, or (in this country) of Mason.

‡ Hygrometrical Tables, 6th edition, 1877. A copy is now sent to each station.

*Weight in Grains of a Cubic Foot of Vapour, under the pressure of 30 inches of Mercury for every degree of temperature from 0° to 100°. The temperature is the dew-point, and the weight of vapour is the weight which can be sustained at that temperature without being visible.*

| Temp. Fahr. | Weight in grains of a Cubic Foot of Vapour. | Temp. Fahr. | Weight in grains of a Cubic Foot of Vapour. | Temp. Fahr. | Weight in grains of a Cubic Foot of Vapour. | Temp. Fahr. | Weight in grains of a Cubic Foot of Vapour. |
|---|---|---|---|---|---|---|---|
| ° | grs. | ° | grs. | ° | grs. | ° | grs. |
| 32 | 2·13 | 50 | 4·10 | 67 | 7·27 | 84 | 12·40 |
| 33 | 2·21 | 51 | 4·24 | 68 | 7·51 | 85 | 12·78 |
| 34 | 2·30 | 52 | 4·39 | 69 | 7·76 | 86 | 13·17 |
| 35 | 2·48 | 53 | 4·55 | 70 | 8·01 | 87 | 13·57 |
| 36 | 2·48 | 54 | 4·71 | 71 | 8·27 | 88 | 13·98 |
| 37 | 2·57 | 55 | 4·87 | 72 | 8·54 | 89 | 14·41 |
| 38 | 2·66 | 56 | 5·04 | 73 | 8·82 | 90 | 14·85 |
| 39 | 2·76 | 57 | 5·21 | 74 | 9·10 | 91 | 15·29 |
| 40 | 2·86 | 58 | 5·39 | 75 | 9·39 | 92 | 15·74 |
| 41 | 2·97 | 59 | 5·58 | 76 | 9·69 | 93 | 16·21 |
| 42 | 3·08 | 60 | 5·77 | 77 | 9·99 | 94 | 16·69 |
| 43 | 3·20 | 61 | 5·97 | 78 | 10·31 | 95 | 17·18 |
| 44 | 3·32 | 62 | 6·17 | 79 | 10·64 | 96 | 17·68 |
| 45 | 3·44 | 63 | 6·38 | 80 | 10·98 | 97 | 18·20 |
| 46 | 3·56 | 64 | 6·59 | 81 | 11·32 | 98 | 18·73 |
| 47 | 3·69 | 65 | 6·81 | 82 | 11·67 | 99 | 19·28 |
| 48 | 3·82 | 66 | 7·04 | 83 | 12·03 | 100 | 19·84 |
| 49 | 3·96 | | | | | | |

*Definition of these terms.*—The dew-point is the temperature when the air is just saturated with moisture, so that the least further fall would cause a deposit of water. The quantity of vapour which can be taken up and be made quite invisible to the senses varies with temperature. The preceding table gives the weight of a cubic foot of vapour, or to use the common, though not quite accurate, phrase, the weight of vapour in a cubic foot of air at different temperatures when the air is saturated with moisture.

The dew-point is obtained *directly* by Daniell's or Regnault's hygrometer, which enables us to cool and note the temperature of a bright surface until the dew is deposited on it, or *indirectly* by means of the dry and wet bulbs.

Unless the air is saturated, the temperature of the wet bulb (*i.e.*, the temperature of evaporation) is always above the dew-point, but is below the temperature of the dry bulb, being reduced by the evaporation. If the dry and wet bulbs are of the same temperature, the air is saturated with moisture, and the temperature noted is the dew-point; if they are not of the same temperature, the dew-point is at some distance below the wet bulb temperature.* It can then be calculated out in two ways.

(*a*) By Mr Glaisher's factors. By comparison of the result of Daniell's hygrometer and the dry and wet bulb thermometers for a long term of years, Mr Glaisher has deduced an empirical formula, which is thus worked. Take the difference of the dry and wet bulb, and multiply it by the factor which stands opposite the *dry bulb* temperature in the following table, deduct the product from the *dry* bulb temperature, the result is the dew-point.

The dew-point being obtained, the amount of vapour in a cubic foot of air is at once seen by looking at the table before given. From this formula Mr Glaisher's tables have been calculated.

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* Occasionally the wet-bulb may read higher than the dry, as in thick fog or during very calm, cold weather. This is rare, but, should it be met with, then the temperature of the dry-bulb is to be taken and considered to be at saturation (Scott).

(*b*) *Apjohn's Formula.*—From a most philosophical and exhaustive analysis of the conditions of this complicated problem, Dr Apjohn has derived his celebrated formula which is now in general use. Reduced to its most simple expression, it is thus worked:—A table of the elastic tension of vapour, in inches of mercury at different temperatures, must be used. From this table take out the elastic tension of the temperature of the *wet* thermometer, and call it $f'$. Let $(t - t')$ be the difference of the two thermometers, and $p$ the observed height of the barometer. Apjohn's formula then enables us to calculate the elastic tension of the dew-point, which we will call $f''$; and this being known by looking in the table, we obtain, opposite this elastic tension, the dew-point temperature.

The formula is:
$$f'' = f' - 0{\cdot}01147(t - t')\frac{p - f'}{30}.$$

The fraction $\frac{p - f'}{30}$ differs but little from unity, and may be neglected; the formula then becomes, for temperatures above 32° Fahr.:
$$f'' = f' - \frac{(t - t')}{87}.$$

If below 32° the formula is: $f'' = f' - \frac{(t - t')}{96}$.

The dew-point being known, the weight of a cubic foot of vapour, and the amount of elastic tension, expressed in inches of mercury (if this is desired), are taken from tables; the relative humidity is got by calculation.

*Glaisher's Factors*—(See previous page):—

| Reading of Dry-bulb Therm. | Factor. | Reading of Dry-bulb Therm. | Factor. | Reading of Dry-bulb Therm. | Factor. | Reading of Dry-bulb Therm. | Factor. |
|---|---|---|---|---|---|---|---|
| 10° | 8·78 | 33° | 3·01 | 56° | 1·94 | 79° | 1·69 |
| 11 | 8·78 | 34 | 2·77 | 57 | 1·92 | 80 | 1·68 |
| 12 | 8·78 | 35 | 2·60 | 58 | 1·90 | 81 | 1·68 |
| 13 | 8·77 | 36 | 2·50 | 59 | 1·89 | 82 | 1·67 |
| 14 | 8·76 | 37 | 2·42 | 60 | 1·88 | 83 | 1·67 |
| 15 | 8·75 | 38 | 2·36 | 61 | 1·87 | 84 | 1·66 |
| 16 | 8·70 | 39 | 2·32 | 62 | 1·86 | 85 | 1·65 |
| 17 | 8·62 | 40 | 2·29 | 63 | 1·85 | 86 | 1·65 |
| 18 | 8·50 | 41 | 2·26 | 64 | 1·83 | 87 | 1·64 |
| 19 | 8·34 | 42 | 2·23 | 65 | 1·82 | 88 | 1·64 |
| 20 | 8·14 | 43 | 2·20 | 66 | 1·81 | 89 | 1·63 |
| 21 | 7·88 | 44 | 2·18 | 67 | 1·80 | 90 | 1·63 |
| 22 | 7·60 | 45 | 2·16 | 68 | 1·79 | 91 | 1·62 |
| 23 | 7·28 | 46 | 2·14 | 69 | 1·78 | 92 | 1·62 |
| 24 | 6·92 | 47 | 2·12 | 70 | 1·77 | 93 | 1·61 |
| 25 | 6·53 | 48 | 2·10 | 71 | 1·76 | 94 | 1·60 |
| 26 | 6·08 | 49 | 2·08 | 72 | 1·75 | 95 | 1·60 |
| 27 | 5·61 | 50 | 2·06 | 73 | 1·74 | 96 | 1·59 |
| 28 | 5·12 | 51 | 2·04 | 74 | 1·73 | 97 | 1·59 |
| 29 | 4·63 | 52 | 2·02 | 75 | 1·72 | 98 | 1·58 |
| 30 | 4·15 | 53 | 2·00 | 76 | 1·71 | 99 | 1·58 |
| 31 | 3·70 | 54 | 1·98 | 77 | 1·70 | 100 | 1·57 |
| 32 | 3·32 | 55 | 1·96 | 78 | 1·69 | | |

The relative humidity is merely a convenient term to express comparative dryness or moisture. Complete saturation being assumed to be 100, any degree of dryness may be expressed as a percentage of this, and is obtained at once by dividing the weight of vapour actually determined by the weight of vapour which would have been present had the air been saturated.

In order to save trouble, all these points, and other matters of interest, such as the weight of a cubic foot of dry air, or of mixed dry and moist air, are given in Mr Glaisher's Hygrometrical Tables, which are now sent to the principal stations, and which all medical officers are advised to get. But in the absence of these, the tables given in this chapter, and Glaisher's factors, will enable the chief points to be determined; also the table, page 455, which is extracted from Mr Glaisher's larger tables, will be found useful. It gives the relative humidity, and if the weight of a cubic foot of vapour (in the table already given, p. 452) at the temperature of the dry bulb, be multiplied by the relative humidity, and then divided by 100, the actual weight of vapour in the air at the time of observation is obtained.[*]

To read the table, take the temperature of the dry bulb, and the difference between it and the wet bulb, and look in the table at the intersection of the two columns.

The amount of watery vapour can also be told by a hair hygrometer. A modification of Saussure's hygrometer is still used in France, and also in Russia and Norway. A human hair, freed from fat by digestion in liquor potassæ or ether, is stretched between a fixed point and a small needle, which traverses a scale divided into 100 parts. As the hair shortens or elongates the needle moves and indicates the relative humidity.[†] The scale is graduated by wetting the hair for complete saturation, and by placing it over sulphuric acid of known strength for different degrees of saturation.[‡] A very delicate instrument is thus obtained, which indicates even momentary changes in moisture. On comparison with the wet and dry bulb, I have found that it gives accordant results for three or four months; it then loses its delicacy, and requires to be a little wound up. If compared with the dry and wet bulb, the hair hygrometer seems to be exact enough for experiments in ventilation, for which it is adapted from its rapidity of indication. It has also been recommended by the Vienna congress for use in extreme climates, when the indications of the psychrometer are either uncertain or entirely astray.[§] The amount of watery vapour in the air has a considerable effect on the temperature of a place. Hermann von Schlagintweit[‖] has pointed out that the differences between the temperature marked in the sun and shade by two maximum thermometers are chiefly dependent on the amount of humidity. The maxima of insolation (measured by the difference between the sun and shade thermometers) occur in those stations and on those days when humidity is greatest. Thus, at Calcutta, the relative humidity being 88 to 93, the insolation (or difference between the thermometers) is 50° Fahr.; at Bellari the relative humidity being 60 to 65, the insolation is 8° to 11°. These results are explained by Tyndall's observations, which show that the transparent humidity will scarcely affect the sun's rays striking on the sun thermometer, while it greatly obstructs the radiation of invisible heat from the thermometer; when the air is highly charged with moisture, the sun

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[*] Or, what is the same thing, multiply by the relative humidity, with a decimal point before it.

[†] Hair shortens when dry and elongates when moist.

[‡] The graduation of the scale is explained in The Arctic Manual, p. 16.

[§] See Scott's Instructions, p. 47.

[‖] Proceedings of Royal Soc. vol. xiv. p. 111, 1865.

TABLE *of the Relative Humidity given by the difference between the Dry and Wet Bulb.*

| Temperature of the Dry Bulb. | DIFFERENCE BETWEEN THE DRY AND WET BULB. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | RELATIVE HUMIDITY, SATURATION = 100. | | | | | | | | | | | | | | | |
| 90 | 100 | 95 | 90 | 85 | 81 | 77 | 73 | 69 | 65 | 62 | 59 | 56 | 53 | 50 | 47 | 44 |
| 89 | 100 | 95 | 90 | 85 | 81 | 77 | 73 | 69 | 65 | 61 | 58 | 55 | 52 | 49 | 46 | 43 |
| 88 | 100 | 95 | 90 | 85 | 81 | 77 | 73 | 69 | 65 | 61 | 58 | 55 | 52 | 49 | 46 | 43 |
| 87 | 100 | 95 | 90 | 85 | 81 | 77 | 73 | 69 | 65 | 61 | 58 | 55 | 52 | 49 | 46 | 43 |
| 86 | 100 | 95 | 90 | 85 | 80 | 76 | 72 | 68 | 64 | 61 | 58 | 55 | 52 | 49 | 46 | 43 |
| 85 | 100 | 95 | 90 | 85 | 80 | 76 | 72 | 68 | 64 | 61 | 58 | 55 | 52 | 49 | 46 | 43 |
| 84 | 100 | 95 | 90 | 85 | 80 | 76 | 72 | 68 | 64 | 60 | 57 | 54 | 51 | 48 | 45 | 43 |
| 83 | 100 | 95 | 90 | 85 | 80 | 76 | 72 | 68 | 64 | 60 | 57 | 54 | 51 | 48 | 45 | 42 |
| 82 | 100 | 95 | 90 | 85 | 80 | 76 | 72 | 68 | 64 | 60 | 57 | 54 | 51 | 48 | 45 | 42 |
| 81 | 100 | 95 | 90 | 85 | 80 | 76 | 72 | 68 | 64 | 60 | 56 | 53 | 50 | 47 | 44 | 41 |
| 80 | 100 | 95 | 90 | 85 | 80 | 75 | 71 | 67 | 63 | 59 | 56 | 53 | 50 | 47 | 44 | 41 |
| 79 | 100 | 95 | 90 | 85 | 80 | 75 | 71 | 67 | 63 | 59 | 56 | 53 | 50 | 47 | 44 | 41 |
| 78 | 100 | 94 | 89 | 84 | 79 | 75 | 71 | 67 | 63 | 59 | 56 | 53 | 50 | 47 | 44 | 41 |
| 77 | 100 | 94 | 89 | 84 | 79 | 75 | 71 | 67 | 63 | 59 | 56 | 53 | 50 | 47 | 44 | 41 |
| 76 | 100 | 94 | 89 | 84 | 79 | 75 | 71 | 67 | 63 | 59 | 55 | 52 | 49 | 46 | 43 | 40 |
| 75 | 100 | 94 | 89 | 84 | 79 | 74 | 70 | 66 | 62 | 58 | 55 | 52 | 49 | 46 | 43 | 40 |
| 74 | 100 | 94 | 89 | 84 | 79 | 74 | 70 | 66 | 62 | 58 | 55 | 52 | 48 | 45 | 43 | 40 |
| 73 | 100 | 94 | 89 | 84 | 79 | 74 | 70 | 66 | 62 | 58 | 54 | 51 | 48 | 45 | 42 | 40 |
| 72 | 100 | 94 | 89 | 84 | 79 | 74 | 69 | 65 | 61 | 57 | 54 | 51 | 48 | 45 | 42 | 39 |
| 71 | 100 | 94 | 88 | 83 | 78 | 73 | 69 | 65 | 61 | 57 | 53 | 50 | 47 | 44 | 41 | 38 |
| 70 | 100 | 94 | 88 | 83 | 78 | 73 | 69 | 65 | 61 | 57 | 53 | 50 | 47 | 44 | 41 | 38 |
| 69 | 100 | 94 | 88 | 83 | 78 | 73 | 68 | 64 | 60 | 56 | 53 | 50 | 47 | 44 | 41 | 48 |
| 68 | 100 | 94 | 88 | 83 | 78 | 73 | 68 | 64 | 60 | 56 | 52 | 49 | 46 | 43 | 40 | 37 |
| 67 | 100 | 94 | 88 | 83 | 78 | 73 | 68 | 64 | 60 | 56 | 52 | 49 | 46 | 43 | 40 | 37 |
| 66 | 100 | 94 | 88 | 83 | 78 | 73 | 68 | 64 | 60 | 56 | 52 | 48 | 45 | 42 | 40 | 37 |
| 65 | 100 | 94 | 88 | 83 | 78 | 73 | 68 | 63 | 59 | 55 | 51 | 48 | 45 | 42 | 39 | 36 |
| 64 | 100 | 94 | 88 | 82 | 77 | 72 | 67 | 63 | 59 | 55 | 51 | 48 | 44 | 42 | 39 | 36 |
| 63 | 100 | 94 | 88 | 82 | 77 | 72 | 67 | 63 | 59 | 55 | 51 | 47 | 44 | 41 | 38 | 35 |
| 62 | 100 | 94 | 88 | 82 | 77 | 72 | 67 | 62 | 58 | 55 | 50 | 47 | 44 | 41 | 38 | 35 |
| 61 | 100 | 94 | 88 | 82 | 77 | 72 | 67 | 62 | 58 | 54 | 50 | 47 | 44 | 41 | 38 | 35 |
| 60 | 100 | 94 | 88 | 82 | 76 | 71 | 66 | 62 | 58 | 54 | 50 | 46 | 43 | 40 | 37 | 34 |
| 59 | 100 | 94 | 88 | 82 | 76 | 71 | 66 | 61 | 57 | 53 | 49 | 46 | 43 | 40 | 37 | 34 |
| 58 | 100 | 93 | 87 | 81 | 76 | 71 | 66 | 61 | 57 | 53 | 49 | 46 | 43 | 40 | 37 | 34 |
| 57 | 100 | 93 | 87 | 81 | 75 | 70 | 65 | 61 | 57 | 53 | 49 | 45 | 42 | 39 | 36 | 33 |
| 56 | 100 | 93 | 87 | 81 | 75 | 70 | 65 | 60 | 56 | 52 | 48 | 44 | 41 | 38 | 35 | 32 |
| 55 | 100 | 93 | 87 | 81 | 75 | 70 | 65 | 60 | 56 | 52 | 48 | 44 | 41 | 38 | 35 | 32 |
| 54 | 100 | 93 | 86 | 80 | 74 | 69 | 64 | 59 | 56 | 51 | 47 | 43 | 40 | 37 | 34 | 31 |
| 53 | 100 | 93 | 86 | 80 | 74 | 69 | 64 | 59 | 55 | 51 | 47 | 43 | 39 | 36 | 33 | 30 |
| 52 | 100 | 93 | 86 | 80 | 74 | 69 | 64 | 59 | 54 | 50 | 46 | 42 | 39 | 36 | 33 | 30 |
| 51 | 100 | 93 | 86 | 80 | 74 | 68 | 63 | 58 | 54 | 50 | 46 | 42 | 36 | 35 | 32 | 29 |
| 50 | 100 | 93 | 86 | 80 | 74 | 68 | 63 | 58 | 54 | 49 | 45 | 41 | 37 | 34 | 31 | 29 |
| 49 | 100 | 93 | 86 | 79 | 73 | 67 | 62 | 57 | 53 | 49 | 45 | 41 | 37 | 34 | 31 | 28 |
| 48 | 100 | 93 | 86 | 79 | 73 | 67 | 62 | 57 | 52 | 48 | 44 | 40 | 36 | 33 | 30 | |
| 47 | 100 | 93 | 86 | 79 | 73 | 67 | 61 | 56 | 51 | 47 | 43 | 39 | 28 | 33 | 30 | |
| 46 | 100 | 93 | 86 | 79 | 73 | 67 | 61 | 56 | 51 | 47 | 43 | 39 | 36 | 32 | 29 | |
| 45 | 100 | 92 | 85 | 78 | 72 | 66 | 60 | 55 | 50 | 46 | 42 | 38 | 34 | 31 | 28 | |
| 44 | 100 | 92 | 84 | 78 | 71 | 65 | 59 | 54 | 49 | 45 | 41 | 37 | 34 | 31 | 28 | |
| 43 | 100 | 92 | 84 | 78 | 71 | 65 | 59 | 54 | 49 | 45 | 41 | 37 | 34 | 31 | 28 | |
| 42 | 100 | 92 | 84 | 78 | 71 | 66 | 60 | 54 | 49 | 44 | 40 | 36 | 48 | 30 | 27 | |
| 41 | 100 | 92 | 84 | 77 | 70 | 64 | 58 | 53 | 48 | 43 | 39 | 35 | 41 | 28 | | |
| 40 | 100 | 92 | 84 | 77 | 69 | 63 | 57 | 51 | 46 | 42 | 38 | 33 | 31 | | | |
| 39 | 100 | 92 | 84 | 77 | 69 | 63 | 57 | 52 | 47 | 42 | 38 | 34 | | | | |
| 38 | 100 | 91 | 83 | 75 | 68 | 62 | 56 | 50 | 45 | 41 | 37 | | | | | |
| 37 | 100 | 91 | 83 | 75 | 68 | 61 | 55 | 49 | 44 | 39 | | | | | | |
| 36 | 100 | 91 | 82 | 74 | 66 | 59 | 53 | 47 | 42 | | | | | | | |
| 35 | 100 | 90 | 80 | 72 | | | | | | | | | | | | |
| 34 | 100 | 89 | 79 | 72 | | | | | | | | | | | | |
| 33 | 100 | 88 | 78 | 70 | | | | | | | | | | | | |
| 32 | 100 | 87 | 75 | | | | | | | | | | | | | |

thermometer is constantly gaining heat from the sun's rays, while it loses little by radiation, or if it does lose by radiation, gains it again from the air.

When watery vapour mixes with dry air, the volume of the latter is augmented; the weight of a cubic foot of dry air at 60° Fahr. is 536·28 grains, and that of a cubic foot of vapour at 60° is 5·77 grains; the conjoint weights would be 542·05 grains at 60°, but, owing to the enlargement of the air, the actual weight of a cubic foot of saturated air at 60° is only 532·84.

## SECTION III.

### BAROMETER.

A good mercurial barometer is supplied to many army stations; the scale is brass, graduated to 20ths or $\frac{1}{2}$-tenths on the scale, and is read to $\frac{2}{1000}$ths by means of a vernier. There is a movable bottom to the cistern, which is worked up and down by a screw, so as to keep the mercury in the cistern at the same level. Correction for capacity is thus avoided.

*To fix the Barometer.*—Choose a place with a good light, yet protected from direct sunlight and rain; fix the frame sent with the barometer very carefully with a plumb-line, so as to have it exactly perpendicular; then hang the barometer on the hook, and adjust it gently by means of the three screws at the bottom, so that it hangs truly in the centre. Test this by the plumb-line (a 4 oz. weight tied to a string will do), and then unscrew the bottom of the cistern till the ivory point is seen.

Before fixing the barometer the bottom should be unscrewed till the mercury is two or three inches from the top; the barometer should be suddenly inclined, so as to let the mercury fall against the top; if there is no air it will do this with a sharp click; if there be air there is no click; in that case turn the barometer upside down, and tap the side forcibly till you see the globule of air passing up the tube through the mercury into the cistern. Do not be afraid of doing this; if the screw at the bottom be not too far unscrewed there is no danger of any damage to the instrument.

*Reading of Barometer.*—Read the attached thermometer first; then adjust the cistern, so that the ivory point, perceptible through the glass wall of the cistern, seems just to touch the point of the image in the mercury. Then adjust the vernier, so as to cut off the light from the *top* of the mercury. Then read the scale with the bottom of the vernier.

I have found that a little difficulty is experienced in understanding the vernier by those who are not accustomed to such instruments. It will be, probably, comprehended from a little description, read with the instrument before us. On the scale of the barometer itself, it will be seen that the smallest divisions correspond to half-tenths; that is, to $\frac{5}{100}$ths of an inch (= ·05). The height of the mercury can be read so far on the scale itself. The vernier is intended to enable us to read the amount of space the top of the mercury is above or below one of these half-tenth lines. It will be observed that the vernier is divided into twenty-five lines; but on adjusting it, so that its lower-line corresponds with a line indicating an inch, it will be seen that its twenty-five divisions only equal twenty-four half-tenth divisions on the scale. The result is, that each division on the vernier is $\frac{1}{25}$th less than a half-tenth division on the scale. One $\frac{1}{25}$th of a half-tenth is $\frac{2}{1000}$ths of an inch (·05 ÷ 25 = ·002 inch).

This being understood, adjust the vernier so that its *lowest* line accurately corresponds to any line on the scale. It will then be seen that its lowest line but one is a little distance below (in fact, ·002 inch) the next line on the fixed scale. Raise now the vernier, so that its second line shall correspond to the line on the scale to which it was a little below; and of course the bottom of the vernier must be raised ·002 inch above the line it first corresponded with. If the next line, the third on the vernier, be made to correspond with the line on the scale just above it, the bottom of the scale must be raised double this (·004 inch) above the line it was first level with; if the next line on the vernier be made to correspond with a line on the scale, the scale is raised ·006, and so on. Each division on the vernier equals ·002 inch, and each five divisions equals $\frac{1}{100}$th, or ·01 inch.

The barometer is read thus. The vernier being adjusted to the top of the mercury, read on the *scale* to the half-tenth; then look above, and see what line on the *vernier* corresponds exactly to a line on the scale. Then read the number on the vernier, counting from the bottom; multiply it by ·002, and the result is the number of hundredths or thousandths of an inch the top of the mercury is above the half-tenth line next below it.* Add this number to that already got by direct reading of the fixed scale, and the result is the height of the mercury in inches and decimals of an inch.

*Corrections for the Barometer.*—The barometer supplied to military stations requires no correction for capacity. There are two constant corrections for all barometers, viz., capillarity and index error. The first depends on the size of the bore, and whether the mercury has been boiled in the tube or not.

The error for capillarity is notified by the maker. Index error is determined by comparison with a standard barometer. It is indicated by the maker, and is constant by the same barometer. The index and capillarity errors are put together. The capillarity error is always additive; the index error may be subtractive or additive; the two together form a constant quantity. The certificates furnished by the Kew Observatory, for all barometers verified there, include the corrections above mentioned.

*Correction for temperature.*—The barometer is always registered as if the temperature of the mercury were 32° Fahr. If the temperature of the mercury be above this, the metal expands, and reads higher than it would do at 32°. The amount of expansion of mercury is ·0001001 of its bulk for each degree; but the linear expansion of the brass scale must be also considered.

Schumacher's formula is used for the correction—viz.,

$h$ = observed height of barometer in inches.
$t$ = temperature of attached thermometer (Fahr.).
$m$ = expansion of mercury per degree—viz. ·0001001 of its length at 32°.
$s$ = linear expansion of scale—viz. ·00001041; normal temperature being 62°.

$$-h\,\frac{m(t-32^\circ)-s(t-62^\circ)}{1+m(t-32^\circ)}.$$

To facilitate the correction for temperature, tables are given in Mr R. H. Scott's "Instructions in the Use of Meteorological Instruments," which is distributed to medical officers.

*Correction for Sea-Level.*—As the mercury falls about $\frac{1}{1000}$ (·001 inch)† for every foot of ascent, this amount multiplied by the number of feet must be added to the height, if the place be above sea-level.‡ The temperature of the air has, however, also to be taken into account if great accuracy is required.

When all these corrections have been made, the exact height of the mercury represents the conjoint weights of the oxygen, nitrogen, carbonic acid, and watery vapour of the atmosphere. It is difficult to separate these several weights, and the late observations, which show that the humidity existing at any place is merely local, and that vapour is most unequally diffused through the air, render it quite uncertain what amount of the mercury is supported by the watery vapour. Yet that this has a considerable effect in altering the barometric height, particularly in the tropics, seems certain (Herschel).

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* Instead of multiplying the number on the vernier by ·002, a little practice will enable the calculation to be made at once. On the vernier will be seen the figures 1, 2, 3, 4, and 5; corresponding to the 5th, 10th, 15th, 20th, and 25th lines, and indicating ·01, ·02, ·03, ·04, or ·05 inch. Each line between these numbered lines equals ·002 inch.

† The exact amount is a little below this, but varies with altitude; at sea-level the amount is ·000886 for every foot of ascent. See measurement of heights by barometer.

‡ For the British Isles, the mean sea-level at Liverpool has been selected by the Ordnance Survey as their datum.

The height of the barometer at sea-level differs at different parts of the earth's surface; being less at the equator (29·974) than on either side at 30° N. and S. lat., and lessening again towards the poles, especially towards the south, from 63° to 74° S. lat., where the depression is upwards of an inch. It differs in different places also according to their geographical position and their height above sea-level. Like the thermometer, it is subjected to diurnal and annual periodic changes and to non-periodic undulations.

In the tropics the diurnal changes are very steady; there are two maxima and two minima; the first maximum is about 9 A.M.; the first minimum about 3 to 4 P.M.; the second maximum at 10 P.M.; the second minimum at 4 A.M. These changes are, perhaps, chiefly dependent on the watery vapour (Herschel). In this country the diurnal range is less; it falls from midnight to about 4 to 6; rises till 11, and falls again till 4 or 6; then rises till midnight. The undulations depend on the constantly shifting currents of air, rendering the total amount of air over a place heavier or lighter. The wind tends to pass towards the locality of least barometric pressure. In this country the barometer falls with the south-west winds; rises with the north and east; the former are moist and warm, the latter dry and cold winds.

The isobarometric lines are the lines connecting places from the same mean annual height of barometer.

*Measurement of Heights.*—The barometer falls when heights are ascended, as a certain weight of air is left below it. The diminution is not uniform, for the higher the ascent the less weighty the air, and a greater and greater height must be ascended to depress the barometer one inch. This is illustrated by the following table:—*

| | | | | | | |
|---|---|---|---|---|---|---|
| To lower from | 31 | inches to | 30 = | 857 | feet must be | ascended. |
| „ | 30 | „ | 29 = | 886 | „ | „ |
| „ | 29 | „ | 28 = | 918 | „ | „ |
| „ | 28 | „ | 27 = | 951 | „ | „ |
| „ | 27 | „ | 26 = | 986 | „ | „ |
| „ | 26 | „ | 25 = | 1025 | „ | „ |
| „ | 25 | „ | 24 = | 1068 | „ | „ |
| „ | 24 | „ | 23 = | 1113 | „ | „ |
| „ | 23 | „ | 22 = | 1161 | „ | „ |
| „ | 22 | „ | 21 = | 1216 | „ | „ |
| „ | 21 | „ | 20 = | 1276 | „ | „ |
| „ | 20 | „ | 19 = | 1341 | „ | „ |
| „ | 19 | „ | 18 = | 1413 | „ | „ |

The measurements of heights in this way is of great use to medical officers; the aneroid barometer can be used as high as 5000 feet, and a delicate instrument will measure as little as 4 feet. The new pocket aneroids will measure up to 12,000 or 14,000 feet.

A great number of plans are in use for calculating heights. It can be done readily by logarithms, but then medical officers may not possess a table of logarithms.

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* The height can be taken readily from this table, by calculating the number of feet which must have been ascended to cause the observed fall, and then making a correction for temperature, by multiplying the number obtained from the table, which may be called $A$, by the formula ($t$ is the temperature of the lower, and $t'$ of the upper station).

$$\left(1 + \frac{t+t'-64}{900}\right) \times A.$$

The simplest rule of all is one derived from Laplace's formula. Mr Ellis* has lately stated this formula as follows:—Multiply the difference of the barometric readings by 52,400, and divide by the sum of the barometric readings. If the result be 1000, 2000, 3000, 4000, or 5000, add 0, 0, 2, 6, 14, respectively. Substract 2½ times the difference of the temperatures of the mercury. Multiply the remainder by a number obtained by adding 836 to the sum of the temperatures of the air, and dividing by 900. A correction must also be made for latitude, which can be done by Table III. p. 461.

Tables such as those given by Delcros and Oltmanns are very convenient for estimating heights by the barometer. A table less long than these, but based on the same principle, has been given by Negretti and Zambra in their useful work,† and as it is the easiest formula I know, I have copied it.

A good mercurial barometer, with an attached thermometer, or an aneroid compensated for temperature, and a thermometer to ascertain the temperature of the air, are required. Two barometers and two thermometers, which can be observed at the same moment at the upper and lower stations, are desirable.

Supposing, however, there is but one barometer, take the height at the

TABLE I.—*Approximate Height due to Barometric Pressure.*

| Inches of Barometer. | Feet. | Inches of Barometer. | Feet. | Inches of Barometer. | Feet. |
|---|---|---|---|---|---|
| 31·0 | 0 | 27·3 | 3,323 | 23·6 | 7,131 |
| 30·9 | 84 | ·2 | 3,419 | ·5 | 7,242 |
| ·8 | 169 | ·1 | 3,515 | ·4 | 7,353 |
| ·7 | 254 | 27·0 | 3,612 | ·3 | 7,465 |
| ·6 | 339 | 26·9 | 3,709 | ·2 | 7,577 |
| ·5 | 425 | ·8 | 3,806 | ·1 | 7,690 |
| ·4 | 511 | ·7 | 3,904 | 23·0 | 7,803 |
| ·3 | 597 | ·6 | 4,002 | 22·9 | 7,917 |
| ·2 | 683 | ·5 | 4,100 | ·8 | 8,032 |
| ·1 | 770 | ·4 | 4,199 | ·7 | 8,147 |
| 30·0 | 857 | ·3 | 4,298 | ·6 | 8,262 |
| 29·9 | 944 | ·2 | 4,398 | ·5 | 8,378 |
| ·8 | 1,032 | ·1 | 4,498 | ·4 | 8,495 |
| ·7 | 1,120 | 26·0 | 4,588 | ·3 | 8,612 |
| ·6 | 1,208 | 25·9 | 4,699 | ·2 | 8,729 |
| ·5 | 1,296 | ·8 | 4,800 | ·1 | 8,847 |
| ·4 | 1,385 | ·7 | 4,902 | 22·0 | 8,966 |
| ·3 | 1,474 | ·6 | 5,004 | 21·9 | 9,085 |
| ·2 | 1,563 | ·5 | 5,106 | ·8 | 9,205 |
| ·1 | 1,653 | ·4 | 5,209 | ·7 | 9,325 |
| 29·0 | 1,743 | ·3 | 5,312 | ·6 | 9·446 |
| 28·9 | 1,833 | ·2 | 5,415 | ·5 | 9,567 |
| ·8 | 1,924 | ·1 | 5,519 | ·4 | 9,689 |
| ·7 | 2,015 | 25·0 | 5,623 | ·3 | 9,811 |
| ·6 | 2,106 | 24·9 | 5,728 | ·2 | 9,934 |
| ·5 | 2,198 | ·8 | 5,833 | ·1 | 10,058 |
| ·4 | 2,290 | ·7 | 5,939 | 21·0 | 10,182 |
| ·3 | 2,382 | ·6 | 6,045 | 20·9 | 10,307 |
| ·2 | 2,475 | ·5 | 6,152 | ·8 | 10,432 |
| ·1 | 2,568 | ·4 | 6,259 | ·7 | 10,558 |
| 28·0 | 2,661 | ·3 | 6,366 | ·6 | 10,684 |
| 27·9 | 2·754 | ·2 | 6,474 | ·5 | 10,812 |
| ·8 | 2,848 | ·1 | 6,582 | ·4 | 10,940 |
| ·7 | 2,942 | 24·0 | 6,691 | ·3 | 11,069 |
| ·6 | 3,037 | 23·9 | 6,800 | ·2 | 11,198 |
| ·5 | 3,132 | ·8 | 6,910 | ·1 | 11,328 |
| 27·4 | 3,227 | 23·7 | 7,020 | 20·0 | 11,458 |

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* Proceedings of Royal Society, 1865, No. 75, p. 283.

† A Treatise on Meteorological Instruments, by Negretti and Zambra, 1864.

lower station, and correct for temperature to 32°, according to the table given at page 425. Take the temperature of the air. Ascend as rapidly as possible to the upper station, and take the height of the barometer (correcting it to 32°) and the temperature of the air; then use the following tables, taken from Negretti and Zambra's work. If the height is less than 300 feet, Tables II., III., and IV. need not be used.

"Table I. is calculated from the formula, height in feet $= 60{,}200$ (log. $29{\cdot}922$—log. $B) + 925$; where 29·922 is the mean atmospheric pressure at 32° Fahr., and at the mean sea-level in latitude 45°; and $B$ is any other barometric pressure; the 925 being added to avoid minus signs in the table.

"Table II. contains the correction necessary for the mean temperature of the stratum of air between the stations of observation; and is computed from Regnault's co-efficient for the expansion of air, which is ·002036 of its volume at 32° for each degree above that temperature.

Table, III. is the correction due to the difference of gravitation in any other latitude, and is found from the formula, $x = 1 + {\cdot}00265$ cos. 2 lat.

"Table IV. is to correct for the diminution of gravity in ascending from the sea-level.

"To use these tables: The barometer readings at the upper and lower stations having been corrected and reduced to temperature 32° Fahr., take out from Table I. the numbers opposite the corrected readings of the two barometers, and subtract the lower from the upper. Multiply this difference successively by the factors found in Tables II. and III. The factor from Table III. may be neglected unless precision is desired. Finally, add the correction taken from Table IV." (Negretti and Zambra.)

In the table the barometer is only read to 10ths, but it should be read to 100ths (·01) and 1000ths (·001), and the number of feet corresponding to these amounts calculated from the table, which is easy enough.

TABLE II.—*Correction due to Mean Temperature of the Air; the Temperature of the Upper and Lower Stations being added and divided by 2.*

| Mean Temp. | Factor. | Mean Temp. | Factor. | Mean Temp. | Factor. |
|---|---|---|---|---|---|
| 10° | 0·955 | 35° | 1·006 | 60° | 1·057 |
| 11 | ·957 | 36 | 1·008 | 61 | 1·059 |
| 12 | ·959 | 37 | 1·010 | 62 | 1·061 |
| 13 | ·961 | 38 | 1·012 | 63 | 1·063 |
| 14 | ·963 | 39 | 1·014 | 64 | 1·065 |
| 15 | ·965 | 40 | 1·016 | 65 | 1·067 |
| 16 | ·967 | 41 | 1·018 | 66 | 1·069 |
| 17 | ·969 | 42 | 1·020 | 67 | 1·071 |
| 18 | ·971 | 43 | 1·022 | 68 | 1·073 |
| 19 | ·974 | 44 | 1·024 | 69 | 1·075 |
| 20 | ·976 | 45 | 1·026 | 70 | 1·077 |
| 21 | ·978 | 46 | 1·029 | 71 | 1·079 |
| 22 | ·980 | 47 | 1·031 | 72 | 1·081 |
| 23 | ·982 | 48 | 1·033 | 73 | 1·083 |
| 24 | ·984 | 49 | 1·035 | 74 | 1·086 |
| 25 | ·986 | 50 | 1·037 | 75 | 1·088 |
| 26 | ·988 | 51 | 1·039 | 76 | 1·090 |
| 27 | ·990 | 52 | 1·041 | 77 | 1·092 |
| 28 | ·992 | 53 | 1·043 | 78 | 1·094 |
| 29 | ·994 | 54 | 1·045 | 79 | 1·096 |
| 30 | ·996 | 55 | 1·047 | 80 | 1·098 |
| 31 | 0·998 | 56 | 1·049 | 81 | 1·100 |
| 32 | 1·000 | 57 | 1·051 | 82 | 1·102 |
| 33 | 1·002 | 58 | 1·053 | 83 | 1·104 |
| 34 | 1·004 | 59 | 1·055 | 84 | 1·106 |

TABLE III.—*Correction due to Difference of Gravitation in different Latitudes.*

| Latitude. | Factor. | Latitude. | Factor. | Latitude. | Factor. |
|---|---|---|---|---|---|
| 80° | 0·99751 | 50° | 0·99954 | 20° | 1·00203 |
| 75 | 0·99770 | 45 | 1·00000 | 15 | 1·00230 |
| 70 | 0·99797 | 40 | 1·00046 | 10 | 1·00249 |
| 65 | 0·99830 | 35 | 1·00090 | 5 | 1·00261 |
| 60 | 0·99868 | 30 | 1·00132 | 0 | 1·00265 |
| 55 | 0·99910 | 25 | 1·00170 | | |

TABLE IV.

| Height in Thousand Feet. | Corrective Additive. | Height in Thousand Feet. | Corrective Additive. |
|---|---|---|---|
| 1 | 3 | 9 | 26 |
| 2 | 6 | 10 | 30 |
| 3 | 8 | 11 | 33 |
| 4 | 11 | 12 | 37 |
| 5 | 14 | 13 | 41 |
| 6 | 17 | 14 | 44 |
| 7 | 20 | 15 | 48 |
| 8 | 23 | | |

*Example.*—At two stations the barometer read respectively 29·9 and 21·2, the temperatures of the air being 60° and 40°.

| | | |
|---|---|---|
| Barometer at upper station, | 21·2, Table I. | 9,934 |
| ,, lower ,, | 29·9, ,, | 944 |
| Approximate mean height, | | 8,990 |
| Mean temperature 50°, Table II., Factor | | 1·037 |
| Height corrected for temperature, | | 9,323 |
| Latitude (say) 30°, Table III., Factor | | 1·00132 |
| Height corrected for latitude, | | 9,335 |
| Correction from Table IV. | | 26 |
| Height corrected for direct altitude, | | 9,361 |
| Height of lower station above sea-level (say), | | 150 |
| Final corrected height of upper station above sea-level, | | 9,511 |

*Weight of the Air.*—The barometer expresses the weight of the air in inches of mercury. The actual weight can be determined if the reading of the barometer, temperature, and humidity are all known.

The weight of a cubic foot of dry air at 32° Fahr., and normal pressure, is 566·85 grains. For any other temperature the weight can be calculated. Multiply the co-efficient of the expansion of air (viz., ·0020361 for 1° Fahr.) by the number of degrees above 32, the sum added to unity will give the volume of a cubic foot of dry air at that temperature. Divide 566·85 by the number so obtained. The result is the weight of the dry air at the given temperature.

## SECTION IV.

### RAIN.

Rain is estimated in inches; that is, the fall of an inch of rain implies that on any given area, say a square inch of surface, rain has fallen equal to one inch in depth. The amount of rain is determined by a rain-gauge. Two gauges are supplied for military stations; one placed on the ground, one 20 feet above it; in all parts of the world the latter indicates less rain than the lower placed gauge; the reason of this is not very clear, but it appears to be partially due to wind.

Several kinds of gauges are in use. The one used by the Army Medical Department is a round tin box with a rim or groove at the top; a round top with a funnel inside fits on to this groove, which, when filled with water, forms a water valve. The opening above is circular (the circle being made very carefully, and a rim being carried round it to prevent the rain-drops from being whirled by wind out of the mouth), and descends funnel-shaped, the small end of the funnel being turned up to prevent evaporation. The best size for the open top, or in other words, the area of the receiving surface, is from 50 to 100 square inches. The lower part of the box is sunk in the ground nearly to the groove; the upper part is then put in, and a glass vessel is placed below the funnel to receive the water.* At stated times (usually at 9 A.M. daily) the top is taken off, the glass vessel taken out, and the water weighed or measured. The latter is easiest, and is done in a glass vessel which is graduated to an inch and hundreths of an inch, and is sent with the gauge. Each gauge has its own measure.

If this glass is broken it can be replaced by the following rule, or a rain-gauge can be made by any one very easily. It need not be round, though this is now thought the best form, but may be a square box of metal or wood, and may be of any size between 3 and 24 inches in diameter, but 5 to 8 is the most convenient range.

Determine the area, in square inches, of the receiving surface, or top of the gauge, by careful measurement (see Measurement of Rooms, chapter on AIR). This area, if covered with water to the height of one inch, would give us a corresponding amount of cubic inches. This number of cubic inches is the measure for that gauge of one inch, because when the rain equals that quantity it shows that one inch of rain has fallen over the whole surface.

Let us say the area of the receiving surface is 100 square inches. Take 100 cubic inches of water and put it into a glass, put a mark at the height of the fluid, and divide the glass below it into 100 equal parts. If the rainfall comes up to the mark, one inch of rain has fallen on each square inch of surface; if it only comes up to a mark below, some amount less than an inch (which is so expressed in $\frac{1}{10}$ths and $\frac{1}{100}$ths) has fallen.

To get the requisite number of cubic inches of water we can weigh or measure. A cubic inch of water at 62° weighs 252·458 grains, consequently 100 cubic inches will be (252·458 × 100) = 25245·8 grains, or 57·7 ounces avoir. But an easier way still is to measure the water,—an ounce avoir. is equal to 1·733 cubic inches, therefore divide 100 by 1·733, and we obtain the number of ounces avoir. which corresponds to 100 cubic inches.

Usually a one-inch measure is so large a glass, that half an inch is considered more convenient.

If snow falls instead of rain, it must be melted and the resulting water measured. This may be easily done by adding a measured quantity of warm water, and then subtracting the amount from the total bulk of water.

From the table of the weight of vapour already given, it will be seen that the amount of vapour which can be rendered insensible, increases with the temperature, but not regularly; more, comparatively, is taken up by the high temperatures; thus, at 40°, 2·86 grains are supported; at 50°, 4·10 grains, or 1·24 grains more; at 60°, 5·77 grains, or 1·67 grains more than at 50°. Therefore, if two currents of air of unequal temperatures, but equally saturated with moisture, meet in equal volume, the temperature will be the mean of the two, but the amount of vapour which will be kept invisible is less than the mean, and some vapour therefore necessarily falls as fog or rain. Thus one saturated current being at 40°, and the other at 60°, the resultant temperature will be 50°, but the amount of invisible vapour will not be the mean, viz., 4·315, but 4·1; an amount equal to ·215 will therefore be deposited.

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* A glass vessel should not be used in winter, for fear of breakage in frost.

Rain is therefore owing to the cooling of a saturated air, and rain is heaviest under the following conditions,—when the temperature being high, and the amount of vapour large, the hot and moist air soon encounters a cold air. These conditions are chiefly met with in the tropics, when the hot air, saturated with vapour, impinges on a chain of lofty hills over which the air is cold. The fall may be 130 to 160 inches, as on the Malabar coast of India, or 180 to 220 in Southern Burmah, or 600 at Cherrapoonjee, in the Khasyah Hills. Even in our own country the hot air from the Gulf Stream impinging on the Cumberland Hills causes, in some districts a fall of 80, 100, and even 130 inches in the year.

The rainfall in different places is remarkably irregular from year to year; thus at Bombay the mean being 76, in 1822 no less than 112 inches, while in 1824 only 34 inches fell.

The amount of rain in the different foreign stations is given under the respective headings.

## SECTION V.

## EVAPORATION.

The amount of evaporation from a given moist surface is a problem of great interest, but it is not easy to determine it experimentally, and no instrument is issued by the Army Medical Department. A shallow vessel of known area, protected round the rim by wire to prevent birds from drinking, is filled with a known quantity of water, and then, weekly or monthly, the diminution of the water is determined, the amount of addition by rain being at the same time determined by a rain-gauge. This plan takes no notice of dew, and is not regarded as satisfactory.

Another plan is placing water under a cover, which may protect it from rain and dew, and yet permit evaporation, and weighing the loss daily. It is difficult, however, to insure that the evaporation shall be equal to that under the free heavens.

A third plan is calculating the rate of evaporation from the depression of the wet-bulb thermometer, by deducting the elastic force of vapour at the dew-point temperature from the elastic force at the air temperature, and taking the difference as expressing the evaporation. This difference expresses the force of escape of vapour from the moist surface.

Instruments termed Atmometers have been used for this purpose; the first was invented by Leslie. A ball of porous earthenware was fixed to a glass tube, with divisions, each corresponding to an amount of water which would cover the surface of the ball with a film equal to the thickness of $\frac{1}{1000}$th part of an inch. The evaporation from the surface of the ball was then read off. Dr Babington has also invented an ingenious "Atmidometer."[*]

The amount of evaporation is influenced by temperature, wind, humidity of the air, rarefaction of the air, degree of exposure or shading, and by the nature of the moist surface; it is greater from moist soil than from water.

The amount of vapour annually rising from each square inch of water surface in this country has been estimated at from 20 to 24 inches; in the tropical seas it has been estimated at from 80 to 130, or even more inches. In the Indian Ocean it has been estimated at as much as an inch in twenty-four hours, or 365 in the year, an almost incredible amount. No doubt, however, the quantity is very great.

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[*] See Negretti and Zambra's Treatise, p. 141, for details.

It requires an effort of imagination to realise the immense distillation which goes on from the tropical seas. Take merely 60 inches as the annual distillation, and reckon this in feet instead of inches, and then proceed to calculate the weight of the water rising annually from such a small space as the Bay of Bengal. The amount is almost incredible.

This distillation of water serves many great purposes; mixing with the air it is a vast motive power, for its specific gravity is very low (·6235, air being 1), and it causes an enlargement of the volume of air; the moist air is therefore much lighter, and ascends with great rapidity; the distillation also causes an immense transference of heat from the tropics, where the evaporation renders latent a great amount of heat, to the extra-tropical region where this vapour falls as rain, and consequently parts with its latent heat. The evaporation also has been supposed to be a great cause of the ocean currents (Maury), which play so important a part in the distribution of winds, moisture, and warmth.

For physicians the amount of evaporation is a very important point, not merely as influencing the moisture of the air abstractedly, but as affecting the evaporation from the skin and lungs. The evaporating power of the air is inversely to its relative humidity in a still air; it is of course influenced by winds and their temperature, and the vessels and the nerves of the skin are then affected, and evaporation may be accelerated by the physical conditions of motion and warmth, or may be lessened by the physiological action of the wind. The problem is thus a complicated one. (See CLIMATE.)

## SECTION VI.

## WIND.

*Direction.*—For determining the direction of the wind a vane is necessary. It should be placed in such a position as to be able to feel the influence of the wind on all sides, and not be subjected to eddies by the vicinity of buildings, trees, or hills. The points must be fixed by the compass; the magnetic declination being taken into account; the declination of the place must be obtained from the nearest Observatory; in this country it is now about 21° (or two points) to the westward of true north.* The direction of the wind is registered twice daily in the army returns, but any unusual shifting should receive a special note. The course of the wind is not always parallel with the earth; it sometimes blows slightly downwards; contrivances have been employed to measure this, but the matter does not seem important.

Various plans are resorted to for giving a complete summary of the winds, but these are not required from the medical officer.

*Velocity.*—A small Robinson's anemometer is now supplied to each station; it is read every twenty-four hours, and marks the horizontal movement in the preceding twenty-four hours.

This anemometer usually consists of four small cups,† fixed on horizontal axes of such a length (1·12 feet between two cups), that the centre of a cup,

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* Thus N. magnetic will be N.N.W. true, S. magnetic S.S.E. true, and so on.

† The current of air is opposed one-fourth more by a concave surface than by a convex one the same size.

## FORMS OF VARIOUS CLOUDS.

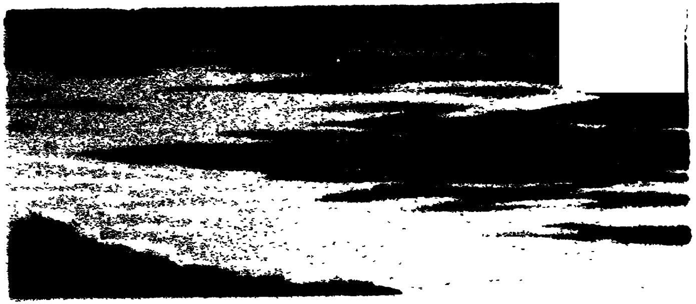

Fig 3 Cirro-stratus [illegible]

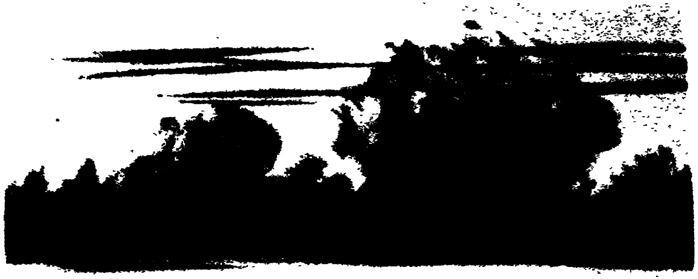

Fig [illegible] Cumulo-stratus ([illegible])

Fig 4 Stratus [illegible]

[illegible]

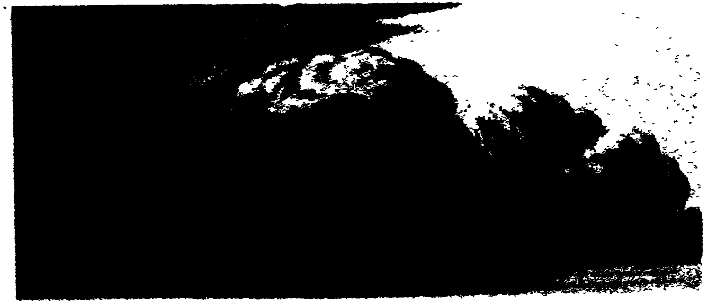

Fig [illegible] Nimbus [illegible]

[illegible]

in revolving a circle, passes over $\frac{1}{1500}$th of a mile, the circle being 3·52 feet. These cups revolve with a third of the wind's velocity; 500 revolutions of the cups therefore indicate one mile. By an arrangement of wheels, the number of miles traversed by the cups in any given time is registered.

Osler's anemometer is a large and very beautiful instrument. It registers at the same time on a piece of paper fitted on a drum, which turns with clockwork, direction, velocity, and pressure.

Other anemometers, Lind's, Whewell's, &c., need not be described.

The average velocity of wind in this country on the surface of the earth is from six to eight miles per hour; its range is from zero to 60 or even 70 miles per hour, but this last is very rare; it is seldom more, even in heavy winds, than 35 to 45 miles per hour. In the hurricanes of the Indian and China seas it is said to reach 100 to 110 miles per hour.

*Force.*—The force of the wind is reckoned as equal to so many pounds or parts of a pound on a square foot of surface. Osler's anemometer registers the force as well as the velocity and direction, but Robinson's (used in the army) only marks the velocity; the force must then be calculated. The rule for the calculation of the force from the velocity is as follows:—

Ascertain the velocity for one hour by observing the velocity for a minute, and multiplying by 60; then square the hour velocity and multiply by ·005. The result is the pressure in pounds or parts of a pound per square foot.

The formula is, if V = velocity per hour,

$$V^2 \times \cdot 005 = P.$$

If the force be given, the velocity may be found:

$$\sqrt{200\,P} = V.$$

When no anemometer is in use, the Beaufort scale may be employed, 0 = calm, about 3 miles an hour,—and 12 = hurricane, 90 miles and over.

## SECTION VII.

## CLOUDS (PLATE IX.)

The nomenclature proposed by Howard* is now universally adopted.

There are three principal forms and four modifications.

### *Principal Forms.*

*Cirrus.*—Thin filaments, which by association form a brush, or woolly hair, or a slender net-work. They are very high in the atmosphere, probably more than ten miles, but the exact height is unknown. It has even been questioned whether they are composed of water; if so, it must be frozen. In this climate they come from the north-west.

*Cumulus.*—Hemispherical or conical heaps like mountains rising from a horizontal base; cumuli are often compared to balls of cotton.

*Stratus.*—A widely-extended, continuous horizontal sheet, often forming at sunset.

### *Modifications.*

*Cirro-cumulus.*—Small rounded, well-defined masses, in close, horizontal arrangement; when the sky is covered with such clouds it is said to be fleecy.

*Cirro-stratus.*—Horizontal strata or masses, more compact than the cirri; at the zenith they seem composed of a number of thin clouds; at the horizon they look like a long narrow band.

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* Climate of London.

*Cumulo-stratus.*—Cirro-stratus blended with the cumulus.

*Cumulo-cirro-stratus, Nimbus, or Rain-cloud.*—A horizontal sheet above which the cirrus spreads, while the cumulus enters it laterally or from below.

Of the above forms Nos. 1, 2, & 3 of the plate (copied by permission from Mr Scott's "Instructions") are "upper" clouds: the others are "lower" clouds. To those described is added the form shown in No. 5, viz., *Roll-cumulus*, which consists of portions of cumulus rolled into a cylindrical shape, and either separate or packed together, as shown in the plate. Alongside the names in the plates are contractions, which ought to be used in description.

*Estimation of Amount of Cloud.*—This is done by a system of numbers—0 expresses a cloudless sky, 10 a perfectly clouded sky, the intermediate numbers various degrees of cloudiness. To get these numbers, look midway between the horizon and zenith, and then turn slowly round, and judge as well as can be done of the relative amount of clear and clouded sky. This is to be entered without reference to the thickness of the cloud: the latter may be indicated by an exponent applied to the figure for the amount of cloud (0 slight, 2 great).

## SECTION VIII.

### OZONE.*

The nature of ozone has been already referred to (p. 442).

Papers covered with a composition of iodide of potassium and starch, and exposed to the air, are supposed to indicate the amount of ozone present in the atmosphere. Schönbein, the discoverer of ozone, originally prepared such papers, and gave a scale by which the depth of blue tint was estimated. Subsequently similar but more sensitive papers were prepared by Dr Moffat, and lately Mr Lowe has improved Moffat's papers, and has also prepared some ozone powders.

The papers are exposed for a definite time to the air, if possible with the exclusion of light, and the alteration of colour is compared with a scale.

Schönbein's proportions are—1 part of *pure* iodide of potassium, 10 parts starch, and 200 parts of water. Lowe's proportion is 1 part of iodide to 5 of starch; Moffat's proportion is 1 to 2½. The starch should be dissolved in cold water, and filtered so that a clear solution is obtained; the iodide is dissolved in another portion of water, and is gradually added. Both must be perfectly pure; the best arrowroot should be used for starch.

The paper prepared by being cut into slips (so as to dry quicker and to avoid loss of the powder in cutting) and soaked in distilled water, is placed in the mixed iodide and starch for four or five hours, then removed with a pair of pincers, and slowly dried in a cool dark place, in a horizontal position. The last point is important, as otherwise a large amount of the iodide drains down to one end of the paper, and it is not equally diffused. The papers when used should hang loose in a place protected from the sun and rain: a box is unnecessary; they should not be touched more than can be helped with the fingers when they are adjusted.

When Schönbein's papers are used they are moistened with water after exposure, but before the tint is taken. Moffat's papers are prepared somewhat similarly to Schönbein's, but do not require moistening with water. Mr Lowe has lately prepared some very sensitive papers which give very uniform results.

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* For a full account of the tests for ozone, see Dr Fox's work on Ozone and Antozone, 1873, already referred to. After discussing all the tests, he gives the preference to the iodine plan. He has not found Schönbein's thallium method satisfactory.

The estimation of ozone is still in a very unsatisfactory state, and this arises from two circumstances.

1. The fact that other substances besides ozone act on the iodide of potassium, especially nitrous acid, which is formed in some quantity during electrical storms. Cloez has shown that air taken about one metre above the ground often contains nitrous acid in sufficient quantity to redden litmus. Starch and iodide paper is coloured when air contains ·00005 of its volume of nitrous acid.

2. The fact that the papers can scarcely be put under the same conditions from day to day; light, wind, humidity, and temperature (by expelling the free iodine) all affect the reaction.

Chemical objections have also been made.* Supposing that iodine is set free by ozone, a portion of it is at once changed by additional ozone into iodozone, which is extremely volatile at ordinary temperatures, and is also changed by contact with water into free iodine and iodic acid. Hence a portion of the iodine originally set free never acts on the starch, being either volatilised or oxidised. Again, the iodine and caustic potash set free by the ozone combine in part again, and form iodate and iodide of potassium ($\frac{1}{6}$th of the former and $\frac{5}{6}$ths of the latter), and in this way the blue colour of iodide of starch first produced may be removed. The ozone may possibly, and probably, act on and oxidise the starch itself, and hence another error.

The conclusion arrived at by the Vienna congress was the following: "The existing methods of determining the amount of ozone in the atmosphere are insufficient, and the congress therefore recommends investigations for the discovery of better methods."

## SECTION IX.

## ELECTRICITY.

The instruments used by meteorologists are simple electroscopes, with two gold-leaf pieces which diverge when excited, or dry galvanic piles acting on gold-leaf plates or an index attached to a Leyden jar (Thomson's Electrometer). For further details see Scott's "Instructions," *op. cit.*

## SECTION X.

## THERMOMETER STAND.

A stand is issued by the War-office, and will be provided at every station. Or it would be very easy to make a stand by two or three strata of boards, placed about 6 inches apart, so as to form a kind of sloping roof over the thermometers, which are suspended on a vertical board.

The dry and wet bulb thermometers are placed in the centre; the maximum on the right side, and the minimum on the left. The wood should be cut away behind the bulbs of the maximum and minimum thermometers, so as to expose them freely to the air. The bulbs of the dry and wet bulbs should also fall below the board. In the regular stands, the pole is made to rotate, so as to turn the roof always to the sun.

A much better stand is Stevenson's screen, a square or oblong box, with louvred sides and open below. This is raised upon legs four feet from the ground, placed upon grass. (See Scott's "Instructions," fig. 10, p. 41.).

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* Beiträge zur Ozonometrie, von Dr v. Maach; Archiv. für Wiss. Heilk. band. ii. p. 29.

## SECTION XI.

### WEATHER.

In registering the kind of weather it is well to adhere to the Beaufort notation and symbols, which are carefully explained in Scott's "Instructions." Columns are given in the return to be filled up in this way.

## SECTION XII.

### DISEASES AND VARIATIONS IN THE METEOROLOGICAL ELEMENTS.

The variation in the prevalence of different diseases at a particular place, in connection with the simultaneous variation of meteorological elements, is an old inquiry which has at present led to few results. The reason of this is, that the meteorological elements are only a few out of a great many causes affecting the prevalence and severity of diseases. Consequently, in order to estimate the real value of changes of temperature, pressure, humidity, ozone, &c., the other causes of disease, or of variations in prevalence or intensity, must be recognised and eliminated from the inquiry. The best of the late observations are those by Guy, Ransome, Vernon, Moffat, Tripe, Scoresby-Jackson, and Ballard.* The observations of the last-named observer are very elaborate and careful, but I hesitate to cite them as certain until they are confirmed. They indicate a rise in the amount of sickness with a rise in temperature, but that certain supplementary meteorological conditions (such as the temperature of the night, the daily range, variations in humidity, rainfall, direction of wind), all affect the result. The amount of previous change in the amount of sickness also influences, and in fact it is evident that the problem is in a high degree complicated.

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* Medico-Chirurgical Transactions, vol. l. p. 50.

# CHAPTER XVI.

# INDIVIDUAL HYGIENIC MANAGEMENT.

THIS subject is an extremely large one, and the object of this book does not allow me to discuss it. It would require a volume to itself. I can merely here make a few very general remarks. The application of general hygienic rules to a particular case constitutes individual management.

It is impossible to make general rules sufficiently elastic, and yet precise enough, to meet every possible case. It is sufficient if they contain principles and precepts which can be applied. While individual hygiene should be a matter of study to all of us, it is by no means desirable to pay a constant or minute attention to one's own health. Such care will defeat its object. We should only exercise that reasonable care, thought, and prudence which, in a matter of such moment, every one is bound to take.

Every man, for example, who considers the subject *bonâ fide*, is the best judge of the exact diet which suits him. If he understands the general principles of diet, and remembers the Hippocratic rule, that the amount of food and exercise must be balanced, and that evil results from excess of either, he is hardly likely to go wrong.

"Temperance and exercise," was the old rule laid down, even before Hippocrates,* as containing the essence of health; and if we translate temperance by "sufficient food for wants, but not for luxuries," we shall express the present doctrine.

The nutrition of the body is so affected by individual peculiarities, that there is a considerable variety in the kind of food taken by different persons. The old rule seems a good one, viz., while conforming to the general principles of diet, not to encourage too great an attention either to quantity or to quality, but avoiding what experience has shown to be manifestly bad, either generally, or for the particular individual, to allow a considerable variety and change in amount from day to day, according to appetite.† Proper and slow mastication of the food is necessary; and it is extraordinary how many affections of the stomach called dyspepsia arise simply from faulty mastication, from deficient teeth, or from swallowing the food too rapidly. Many persons who are too thin are so from their own habits; they eat chiefly meat, and eat it very fast; they should eat slowly, and take more bread and starchy substances. Fat persons, on the other hand, by lessening the amount of starch, and taking more exercise, can lessen with the greatest ease the amount of fat to any amount. It must be remembered, however, that there is a certain individual conformation in this respect; some persons are normally fatter or thinner than others.

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* It is quite plain from the context, that Hippocrates, by temperance, meant such an amount of food as would balance, and neither exceed nor fall short of the exercise. He had a clear conception of the development of mechanical force from, and its relation to, food. He lays down rules to show when the diet is in excess of exercise, or the exercise in excess of diet. In either case he traces disease.

† Celsus carried the plan of variety so far as to recommend that men should sometimes eat and drink more than is proper, and should sometimes not exceed; and Lord Bacon has a remark which leads one to believe he held a similar opinion; but there can be no doubt of the incorrectness of this opinion. It has been truly said that the first general rule of Hippocrates, which prescribes continual moderation, is much truer, and the best writers on hygiene, ancient and modern, have decided against Celsus. Besides being erroneous, the rule of Celsus opens a door to intemperance, and, like a harmless sentence in Hippocrates, has been twisted to serve the argument of gourmands. Its influence is felt even at the present day. This much is certain, that probably 80 per cent. of the persons who consult physicians owe their diseases in some way to food, and in many cases they are perfectly aware themselves of their error or bad habit, but, with the singular inconsistency of human nature, either conceal it from the man to whom they are professing perfect openness, or manage to blind themselves to its existence.

The exact amount of exercise must also be a matter of individual decision, it being remembered that great exercise in the free air is a paramount condition of health, and that the healthiest persons are those who have most of it. As a rule, persons take far too little exercise, especially educated women, who are not obliged to work, and the muscles are too often flaccid and ill-nourished.*

Attention to the skin is another matter of personal hygiene. The skin must be kept perfectly clean, and well clothed. Some writers, indeed, have advised that, if food be plentiful, few clothes be worn; but the best authors do not agree in this, but recommend the surface to be well protected. For cleanliness, cold bathing and friction hold the first rank. The effect of cold is to improve apparently the nutrition of the skin, so that it afterwards acts more readily, and when combined with friction, it is curious to see how the very colour and texture of the skin manifestly improve.

The effect of heat on the skin, and especially the action of the Roman or Turkish baths, and their action on health, have certainly not yet been properly worked out, in spite of the numerous papers which have been written. It has not been proved that the strong action of the Turkish bath is more healthy in the long run than the application of cold water. As a curative agent, it is no doubt extremely useful; but as a daily custom, it is yet *sub judice*. Certainly it should not be used without the concluding application of cold to the surface.

Attention has been often very properly directed to the effect of lead and mercurial hair-dyes. It may be worth while to notice that there is a case on record† in which not only was paralysis produced by a lead hair-wash, but lead was recovered from the base of the left hemisphere of the brain. Snuff containing lead has also caused poisoning.

The care of the bowels is another matter of personal hygiene, and is a matter of much greater difficulty than at first sight appears. Constipation, as allowing food to remain even to decomposition, as leading to distention and sacculation of the colon, and to hæmorrhoids, is to be avoided. But, on the other hand, the constant use of purgative medicine is destructive of digestion and proper absorption; and the use of clysters, though less hurtful to the stomach, and less objectionable altogether, is by no means desirable. On the whole, it would seem that proper relief of the bowels can be usually insured by exercise, and especially by bringing the abdominal muscles into play, and by the use of certain articles of diet—viz., pure water in good quantity with meals, the use of bran bread, honey, and such gently laxative food; and that if these do not answer well, it is better to allow a certain amount of constipation than to fall into the frequent use of purgative medicines.

The regulation of the passions must also be left to the individual. The control of morals has baffled the exertions of the priest and the statesman; but perhaps the influence of sexual irregularities on health has never been made the subject of judicious education. The period of puberty corresponds with the most important period of growth, when the bones are consolidating and uniting, and both muscles and nerves are largely absorbing nourishment, and are developing to their fullest power. The too early use of sexual congress, and even more the drain on the system produced by solitary vice, arrests this development to a considerable extent, and prevents the attainment of the strength and endurance which would insure a healthy, vigorous, and happy life. The venereal diseases, which so waste many of the younger men, form only an item in the catalogue of evils—evils which affect at a subsequent period wives and children, and by undermining the health and happiness of the family, influence the state itself. We know that a wide-spread profligacy has eaten away the vigour of nations, and caused the downfall of states; but we hardly recognise that, in a less degree, the same causes are active among us, and never realise what a state might be if its citizens were temperate in all things. It may be difficult to teach these points to the young, and to urge upon them, for their own and other's sakes, the regulation of the passions which physiology teaches to be necessary for personal happiness, for the welfare of the offspring, and for healthy family life; but I think few can doubt that, in some way, the knowledge should be given.

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* Compare the imperfect development of the muscles of the arms in ladies, as shown by the low evening dresses, with the women of the working classes. No one can doubt which is healthiest or which is the most beautiful, until excess of work develops in the muscles of the labouring women the too hard outlines of middle life.

† Virchow's Archiv, band viii. p. 177.

The amount of mental work, and the practice of general good temper and cheerfulness and hope, are other points which each man must himself control. Great mental work can be borne well if hygienic principles of diet, exercise, &c., be attended to. The old authors paid great attention to the regimen of men engrossed in literary work, and laid down particular rules, insisting especially on a very careful and moderate diet, and on exercise.[*]

Hope and cheerfulness are great aids to health, no doubt, from their effect on digestion. Usually, too, they are combined with a quick and active temperament, and with rapid bodily movements and love of exercise.

The individual application of general hygienic rules will differ according to the sex and age,[†] and the circumstances of the person. In the case of children, we have to apply the general rules with as much caution and care as possible, as we must depend on external evidence to prove their utility. In the case of adults, individual experience soon shows whether or not a prescribed rule is or is not beneficial, and what modification must be made in it. It is not, however, every grown person who has the power to modify or change his condition. He may be under the influence of others who, in fact, arrange for him the circumstances of his life. But still, in no case is all self-control taken away; the individual can always influence the conditions of his own health.

Were the laws of health and of physiology better understood, how great would be the effect! Let us hope that matters of such great moment may not always be considered of less importance than the languages of extinct nations, or the unimportant facts of a dead history.

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[*] Plutarch, whose rules on health are excellent and chiefly taken from Hippocrates, compares the over-studious man to the camel in the fable, who, refusing to ease the ox in due time of his load, was forced at last to carry not only the ox's own load, but the ox himself, when he died under his burden.

[†] Galen was the first who pointed out explicitly that hygienic rules must be different for infancy, youth, manhood, and old age—a fourfold division which is still the best. Pythagoras, Iccus, Herodicus, Hippocrates, Polybus, Diocles, Celsus, and others who preceded Galen, appear to have framed rules chiefly for male adults. Galen sub-divided the subject much more systematically. (For a good short account of the early systems, see Mackenzie on The History of Health, and the Art of Preserving it, 1758.)

# CHAPTER XVII.

# DISPOSAL OF THE DEAD.

In densely populated countries the disposal of the dead is always a question of difficulty. If the dead are buried, so great at last is the accumulation of bodies that the whole country round a great city becomes gradually a vast cemetery.[*] In some soils the decomposition of bodies is very slow, and it is many years before the risk of impurities passing into air and water is removed.

After death the buried body returns to its elements, and gradually, and often by the means of other forms of life which prey on it, a large amount of it forms carbonic acid, ammonia, sulphuretted and carburetted hydrogen, nitrous and nitric acids, and various more complex gaseous products, many of which are very fœtid, but which, however, are eventually all oxidised into the simpler combinations. The non-volatile substances, the salts, become constituents of the soil, pass into plants, or are carried away into the water percolating through the ground. The hardest parts, the bones, remain in some soils for many centuries, and even for long periods retain a portion of their animal constituents.

If, instead of being buried, the body is burned, the same process occurs more rapidly and with different combinations; carbonic acid, carbonic oxide (?), nitrogen, or perhaps combinations of nitrogen, water, &c., are given off, and the mineral constituents, and a little carbon, remain behind.

A community must always dispose of its dead either by burial in land or water, or by burning, or chemical destruction equivalent to burning, or by embalming and preserving. Accustomed as we are to land burial, there is something almost revolting, at first sight, at the idea of making the sea the sepulchre, or of burning the dead. Yet the eventual dispersion of our frames is the same in all cases; and it is probably a matter merely of custom which makes us think that there is a want of affection, or of care, if the bodies of the dead are not suffered to repose in the earth that bore them.

In reality, neither affection nor religion can be outraged by any manner of disposal of the dead which is done with proper solemnity and respect to the earthly dwelling-place of our friends. The question should be placed entirely on sanitary grounds, and we then shall judge it rightly.

What, then, is the best plan of disposing of the dead, so that the living may not suffer?

It seems hardly likely that the practice of embalming or mummifying will ever again become common. What is the use of preserving for a few more years the remains which will be an object of indifference to future generations? The next logical step would be to enshrine these remains in some way so as to insure their preservation, and we should return to the vast burial mounds of Egypt. The question will lie between burial in the land or at sea, and burning.

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[*] Nothing, perhaps, testifies more strongly to the antiquity and the extent of the ancient cities in Anatolia than the vast sepulchral remains. On the site of Old Dardanus, the mother of Troy, and stretching from the Hellespont for two or three miles into the hills, the whole country is honeycombed with tombs. It is the same in the neighbourhood of Troy. The burial of the dead, though practised by the most ancient nations, was afterwards superseded by burning, and was only subsequently returned to. As, therefore, these graves represent only a portion of the duration of the city, the immense assemblage of tombs is the more remarkable, and it is impossible to avoid the conclusion that these great cities must have flourished for periods far longer than those which have elapsed since London or Paris, for example, became large centres of population.

At present the question is not an urgent one; but if the population of Europe continues to increase, it will become so in another century or two. Already in this country we have seen, in our own time, a great change; the objectionable practice of interment under and round churches in towns has been given up, and the population is buried at a distance from their habitations. For the present that measure will probably suffice, but in a few years the question will again inevitably present itself.

Burying in the ground appears certainly the most insanitary plan of the three methods. The air over cemeteries is constantly contaminated, and water (which may be used for drinking) is often highly impure. Hence, in the vicinity of graveyards two dangers to the population arise, and in addition, from time to time, the disturbance of an old graveyard has given rise to disease. It is a matter of notoriety that the vicinity of graveyards is unhealthy. How are these dangers to be avoided? The dead may be buried in more or less air-tight vaults; here decay is slow; the products form and escape slowly, though they must eventually escape; the air and water are less contaminated. But the immense expense of such a plan renders it impossible to adopt it for the community generally. Deep burying has the advantage of greater filtration, both for air and water, than shallow burying, and hence it is a good rule to make the grave as deep as possible, and to allow no more than one body in a grave. The admixture of quicklime has been advised; it absorbs some carbonic acid, and forms sulphuret of calcium with the sulphur and sulphuretted hydrogen, but this itself soon decomposes, so that the expense of quicklime seems hardly commensurate with the result. Charcoal would absorb and oxidise the fœtid organic matter, and, if sufficiently cheap, would be a valuable substance to be heaped in graves; but its cost would be probably too great, nor does it entirely hinder putrefaction and the evolution of foul-smelling substances (H. Barker). If a body has to be kept unburied for some time, sawdust and sulphate of zinc, in the proportion of two parts to one, has been found by Herbert Barker,* to be the best application; a thin layer is put over the dead body; or sawdust is sprinkled on the body, and then two or three ounces of carbolic acid thrown over it.

The only means which present themselves, as applicable in all cases, are the deep burial and the use of plants, closely placed in the cemetery. There is no plan which is more efficacious for the absorption of the organic substances, and perhaps of the carbonic acid, than plants, but it would seem a mistake to use only the dark, slow-growing evergreens. The object should be to get the most rapidly growing trees and shrubs, and, in fact, there is no reason, except a feeling of sentiment, why we should introduce into our cemeteries the gloomy and melancholy cypress and yew. Mr Seymour Haden has called attention to the supposed advantages of perishable coffins, so that the putrefactive changes may be carried out as quickly as possible. And certainly, if burying is to continue, it seems reasonable that no undue obstacle should be placed in the way of changes which are sooner or later inevitable.

When, in the course of years, it becomes imperative to reconsider this question, and land burial will have to be modified, many arguments will present themselves to maritime nations in favour of burying in the sea rather than of burning. It is true that the impurities in burning can be well diffused into the atmosphere at large, and would not add to it any perceptible impurity. But if the burning is not complete, fœtid organic matters are given off, which hang cloud-like in the air and may be perceptible, and even hurtful. As a matter of expense, too, the system of incremation would be greater than the burial at sea. In the burial at sea, some of the body at least would go at once to support other forms of life, more rapidly than in the case of land burial, and without the danger of evolution of hurtful products.

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* Deodorisation and Disinfection, British Medical Journal, January 1866.

Burning, or cremation, has attracted much attention of late years. In this country the subject has been discussed by Sir Henry Thompson and Mr Eassie, and abroad much has been written, especially in Germany and Italy, in both which countries the method has been practically tried. It would certainly appear that the body can be disposed of in a very short time and in an inoffensive manner, while the expense would unquestionably be much reduced if the practice became general.

In time of war, and especially in the case of beleagured fortresses, the disposal of the dead becomes often a matter of difficulty. In that case burning may have to be resorted to. If the bodies are buried, they should always be at as great a distance as possible, and as deep as they can be. If procurable, charcoal should be thrown over them ; if it cannot be obtained, sawdust and sulphate of zinc, or carbolic acid may be employed. Quicklime is also commonly used, but is less useful.

At Metz, in 1870, the following plan was adopted :—A pit of about 17 feet in depth was filled with dead, disposed of as follows :—A row of bodies was laid side by side ; above this a second row was placed, with the heads laid against the feet of the first row ; the third row were placed across, and the fourth row in the same way, but with the heads to the feet of the former ; the fifth row were placed as No. 1, and so on. Between each layer of bodies about an inch of lime, in powder, was placed. From 90 to 100 bodies were thus arranged on a length of 6½ feet, and reached to about 6 feet from the surface ; the pit was then filled up with earth, and though 8400 bodies were put in that pit, there were no perceptible emanations at any time.

Around Metz the graves of men and horses and cattle were disinfected with lime, charcoal, and sulphate of iron. Immense exertions were made to clean and disinfect the camps and battle-fields, and in the month of May 1871, from 1200 to 1600 labourers were employed by the Germans. Wherever practicable, the ground was sown with oats or barley, or grass. The hillocks formed by the graves were planted with trees.

In many cases, at Metz, bodies were dug up by the Germans when there was any fear of water-courses being contaminated, or if houses were near. On account of the danger to the workmen, graves containing more than six bodies were left untouched, and the work was always done under the immediate superintendence of a physician. The earth was removed carefully, but not far enough to uncover the corpse ; then one end of the corpse was uncovered, and as soon as uniform or parts of the body were seen, chloride of lime and sawdust, or charcoal and carbolic acid, put in ; the whole earth round the body was thus treated, and the body at length laid bare, lifted and carried away. The second body was then treated in the same way.

Near Sedan, where there were many bodies very superficially buried, burning was had recourse to. Straw mixed with pitch was put into the graves, and was lighted : 1 ton of pitch sufficed for from 15 to 20 bodies. Opinions as to this practice were divided, and it is not certain how many graves were thus dealt with. It seems probable that only the surface of the body was burnt, and when many bodies were together in one grave some were not touched at all. On the whole, the experiment appears to have been unsuccessful.

The Belgian experience at Sedan was in favour of employing chloride of lime, nitric acid, sulphate of iron, and chlorine gas. Carbolic acid did not answer so well. The sulphate of zinc and charcoal, which Barker found so useful, was not tried.

Mr Eassie has lately called attention to the desirability of an ambulatory cremation furnace for the disposal of bodies in war. If such an arrangement proved practicable, it would unquestionably be of immense advantage from a Hygienic point of view.

# CHAPTER XVIII.

## ON THE PREVENTION OF SOME IMPORTANT AND COMMON DISEASES.

There are two modes by which we may attempt to prevent the occurrence of disease.

1. By conforming with the general rules of hygiene, by which the body and mind are brought into a state of more vigorous health.

2. By investigating and removing the causes of the diseases which we find actually in operation. This part of the inquiry is in fact a necessary supplement to the other, though in proportion to the observance of the general rules of hygiene, the causes of disease will gradually be removed. At present, however, we have to deal with the facts before us,—viz., that there are a great number of diseases actually existent which must form the subject of investigation. We proceed in this case from the particular to the general, whereas, in the first mode, we deduce general rules which have to be applied to individual instances.

Hygiene is in this direction an application of etiology, and etiology is the philosophy of medicine; while in its turn the very foundation and basis of etiology is an accurate diagnosis of disease. Unless diseases are completely identified, all inquiry into causes is hopeless. Let us remember, for example, what utter confusion prevailed in our opinions as to causes and preventive measures at the time when typhus and typhoid fevers were considered identical, or when paroxysmal fever and the true yellow fever or vomito were thought to own a common cause. Any useful rules of prevention were simply impossible—as impossible as at present in many of the diseases of nutrition, which, in the proper sense of the word, are yet undiagnosed.

The advance of diagnosis has of late years been owing not merely to improved methods of observation, but to the more complete recognition of the great principle of the invariableness of causation. The sequence of phenomena in the diseased body proceeds with the same regularity and constancy as in astronomy or chemistry. Like causes always produce like effects. To suppose that from the same cause should proceed a sequence of phenomena so utterly distinct as those of typhus and typhoid fever, now seems incredible; yet with a full, or at any rate a sufficient, knowledge of the phenomena, it was at one time almost universally believed that these two perfectly distinct diseases owned a common origin. At the present moment, the superficial resemblance between gout and rheumatism causes them to be put together in almost all systems of nosology, although, with the exception of the joints being affected, the diseases have almost nothing in common.

In proportion as this great principle is still more constantly applied, and as our means of diagnosis advance, and consequently, causes are more satisfactorily investigated, methods of prevention will become obvious and precise. At present they are very far from being so. In many cases they are founded on very imperfect observation; and very frequently all that can be done is to apply general sanitary rules, without attempting to determine what are the special preventive measures which each disease requires.

It is not necessary, however, that we should wait until the causation of any disease is perfectly understood. We must act, as in so many other affairs, on probability; and endeavour to remove those conditions which, in the present state of our knowledge, seem to be the most likely causes of the disease. It may be that, in some cases, we may be attacking only subsidiary or minor causes, and may overlook others equally, or more important. In some cases, indeed, we may overlook entirely the effective causes, and may be fighting with shadows. Still, even from mistakes, progress often arises—indeed, the difficult path of human knowledge is perhaps always through error.

The term cause is applied by logicians to any antecedent which has a share in producing a certain sequence; and it is well known that in many diseases two sets of causes are in operation—one external, and one internal to the body (exciting and predisposing). The investigation of the internal causes, which in some cases are necessary to the action of the external causes, is equally curious and intricate as that of the external causes, and in some respects it is even more obscure; but measures of prevention must deal with them, as well as with the external causes.

In this chapter I can, of course, only venture to enumerate very briefly, and without discussion, what seem to be the best rules of prevention for the principal diseases of soldiers. To enter on the great subject of the prevention of disease generally, and to discuss all the complicated questions connected with causation, would demand a volume.

I have endeavoured to preserve the simple and practical character which I have attempted to give to the other parts of this manual.

## SECTION I.

## THE SPECIFIC DISEASES.[*]

### *Paroxysmal Fevers.*

*External Cause.*—This is presumed to be putrescent, or at any rate, decomposing vegetable matter (see pp. 44, 111, and 331), derived from a moist and putrescent soil, which is carried into the body by the medium of water or of air.[†]

If by water, a fresh source must be obtained. Well water is generally safe, but not always. Rain water may be unsafe, if the tanks are not clean.[‡] If a fresh source cannot be obtained, boiling, charcoal filtration, and alum appear to be the best preventive measures.[§]

If the introduction be by air, and if the locality cannot be left, the most approved plan is elevation to at least 500 feet above *the source of the poison* in temperate climates; and 1000 to 1500 feet in the tropics, or higher still, if possible.[‖] If this plan cannot be adopted, two points must be aimed at—

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[*] In enumerating these diseases, I have followed simply a convenient order, and have only referred to the most common diseases of soldiers.

[†] I have not thought it desirable to allude here to the views of Salisbury that a species of palmella causes intermittents, or to other similar views; they require more investigation before we can practically act on them.

[‡] For instance of propagation by so-called rain-water, see cases at Tilbury Fort, noted at page 46.

[§] Dr Blanc and Mr Prideaux preserved themselves from intermittent fever, in a march in Abyssinia, by always using water in the form of tea or coffee.

[‖] It must be understood that these heights are assumed to be above a marsh. They will not secure from malaria from marshes, if situated at that or a much greater height. A marsh at Erzeroum is 6000 feet above sea-level; one at Puebla, in New Mexico, is 5000 feet; both cause fevers.

viz., to obviate local, and to avoid drifting malaria. Thorough subsoil draining; filling up moist ground when practicable; paving or covering the ground with herbage kept closely cut, are the best plans for the first point. For the second, belts of trees, even walls can be interposed; or houses can be so built, as not to present openings towards the side of the malarious currents.

The houses themselves should be raised above the ground on arches; or, if wooden, on piles. Upper floors only should be occupied. The early morning air, for three hours after sunrise, should be avoided; and next to this, night air.

*Internal Causes.*—The conformation, or structural condition, which permits the external cause to act, is evidently not equal in different individuals, or in different races; but we are quite ignorant of its nature. It is not removed by attacks of the disease; but, on the contrary, after repeated attacks of ague, a peculiar condition (of the nerves?) is produced, in which the disease can be brought on by causes, such as cold or dietetic errors, which could never have caused it in the first instance. The internal predisposition is greatly heightened by poor feeding, anæmia, and probably by scurvy.

To remove the internal causes our only means at present are the administration of antiperiodics, especially quinine; and good and generous living, with iron medicines. The use of flannel next the skin, and of warm clothing generally; warm coffee, and a good meal before the time of exposure to the malaria, and perhaps moderate smoking (?), are the other chief measures. Wine in moderation is part of a generous diet; but spirits are useless, and probably hurtful, unless given considerably diluted.

### *Yellow Fever.*

*External Cause.*—During the last few years the progress of inquiry has entirely disconnected true yellow fever from malaria, though yellowness of the skin is a symptom of some malarious fevers. Yellow fever is a disease of cities and of parts of cities, being often singularly localised, like cholera. In the West Indies it has repeatedly attacked a barrack (at Bermuda, Trinidad, Barbadoes, Jamaica), while no other place in the whole island was affected. In the same way (at Lisbon, Cadiz, and many other places) it has attacked only one section of a town, and, occasionally, like cholera, only one side of a street. In the West Indies it has repeatedly commenced in the same part of a barrack. In all these points, and in its frequent occurrence in non-malarious places, in the exemption of highly malarious places, in its want of relation to moisture in the atmosphere, and its as evident connection with putrefying fæcal and other animal matters, its cause differs entirely from malaria.[*]

If these points were not sufficient, the fact that the agent or poison which causes yellow fever is portable, can be carried and introduced among a community,[†] and is increased in the bodies of those whom it attacks, indicates that the two agencies of yellow fever and paroxysmal fevers are entirely distinct.[‡]

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[*] The belief in the malarious origin of yellow fever, so long and tenaciously held by many American physicians, seems to be losing ground. (See paper by Dr Perry, read before the American Health Association, The Daily Picayune, Nov. 23, 1878.)

[†] Cases of the Bann, Eclair, Icarus, and several others. The late remarkable introduction of yellow fever from Havannah into St Nazaire, in France (near Brest), is most striking, and cannot be explained away. It spread both from the ship, and, in one instance, from persons. (See Aitken's Medicine, 5th edit. 1868; and Report on Hygiene for 1862, in the Army Medical Report, by the author.) The introduction into Rio in 1849, and into Monte Video, are still more striking cases of importation; and a case very similar to that of St Nazaire occurred some years ago at Swansea. (See Report by Dr Buchanan to the Medical officer of the Privy Council, 1866.)

[‡] As more care is taken, the symptoms of the two diseases also are found to be diagnostic,

That great point being considered settled, the inquiry into the conditions of spread of the yellow fever becomes easier. The points to seize are its frequent and regular localisation and its transportation. The localisation at once disconnects it with any general atmospheric wave of poison; it is no doubt greatly influenced by temperature, and is worse when the temperature is above 70° Fahr. Though it will continue to spread in a colder air than was formerly supposed, it does not spread rapidly, and appears to die out, but even temperature does not cause it to become general in a place.

The localising causes are evidently (cases of Lisbon, Gibraltar, West Indies, &c.) connected with accumulation of excreta round dwellings, and overcrowding. Of the former there are abundant instances, and it is now coming out more and more clearly that, to use a convenient phrase, yellow fever, like cholera and typhoid fever, is a fæcal disease. And here we find the explanation of its localisation in the West Indian barracks in the olden time. Round every barrack there were cesspits, often open to sun and air. Every evacuation of healthy and sick men was thrown into perhaps the same places. Grant that yellow fever was somehow or other introduced, and let us assume (what is highly probable) that the vomited and fæcal matters spread the disease, and it is evident why, in St James' Barracks at Trinidad, or St Ann's Barracks at Barbadoes, men were dying by dozens, while at a little distance there was no disease. The prevalence on board ship is as easily explained: Granted that yellow fever is once imported into the ship, then the conditions of spread are probably as favourable as in the most crowded city; planks and cots get impregnated with the discharges, which may even find their way into the hold and bilge. No one who knows how difficult it is to help such impregnation in the best hospitals on shore, and who remembers the imperfect arrangements on board ship for sickness, will doubt this. Then, in many ships, indeed in almost all in unequal degrees, ventilation is most imperfect, and the air is never cleansed.

Overcrowding, and what is equivalent, defective ventilation, is another great auxiliary; and Bone* relates several striking instances.†

The question of the origin of yellow fever is one which cannot be considered in this volume, and at present no preventive rules of importance can be drawn from the discussion.

The chief preventive measures for the external cause are these:—

1. The portability being proved, the greatest care should be taken to prevent introduction, either by sick men, or by men who have left an infected ship. The case of the "Annie Marie" (see "Aitken's Medicine," and "Report on Hygiene" in the "Army Medical Report" for 1862) has made it quite uncertain what period of time should have elapsed before an infected ship can be considered safe; in fact, it probably cannot be safe until the cargo has been discharged and the ship thoroughly cleansed. Still, it appears, that if men leaving an affected place or ship pass into places well ventilated and in fair sanitary condition, they seldom carry the disease; in other words, the disease is seldom portable by men, but it will occur. It appears necessary, also, to

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and if it were not for the constant use of the unhappy term "remittent," the confusion would not have so long prevailed.

An interesting instance of good diagnosis was made by the French at Vera Cruz in 1861. In the spring the vomito prevailed, and then disappeared. Some months afterwards, cases of a disease occurred so like yellow fever that they were at first taken to be that disease, but on a closer examination they were found to be clearly paroxysmal, and to yield to quinine.—*Rec. de Mem. de Méd. Milit.* 1863.

* Yellow fever, by G. F. Bone, Assist-Surg. to the Forces.

† For example, in the same barrack, the windward rooms have been quite healthy, and the leeward rooms attacked. Men in the latter have ceased to have cases of the disease when moved to the former locality. (See a good case in Bone, *op. cit.* p. 18.)

consider that the incubative period is longer than usually supposed, probably often fourteen or sixteen days. In the case of a ship it seems desirable not to consider danger over until at least twenty days have elapsed since the cure or death of the last case, and even at that time to thoroughly fumigate the ship with chlorine and nitrous acid before the cargo is touched. Men working on board such a ship should work by relays, so as not to be more than an hour at a time in the hold.*

In case men sick with yellow fever must be received into a barrack or hospital, they should be isolated, placed in the best ventilated rooms at the top of the house, if possible, or, better still, in separate houses, and all discharges mixed with zinc sulphate and zinc chloride, and separately disposed of, and not allowed to pass into any closet or latrine.

2. The introduction by drinking-waters not being disproved, care should be taken that the possibility of this mode of introduction be not overlooked.

3. Perfect sewerage and ventilation of any station would probably in great measure preserve from yellow fever, but in addition, in the yellow fever zone, elevation is said to have a very great effect, though the confusion between malarious fevers and the vomito renders the evidence on this point less certain, and the late introduction into Newcastle in Jamaica (4200 feet), and the frequent occurrence at Xalapa (4330 feet), as well as its prevalence on high points of the Andes (9000 feet) (A. Smith), show that the effect of mere elevation has been overrated. Still, as a matter of precaution, stations in all yellow-fever districts should be on elevations above 2000, and if possible 3000 feet.

4. If an outbreak of yellow-fever occur in a barrack, it is impossible then to attempt any cleansing of sewers; the only plan is to evacuate the barracks. This has been done many times in the West Indies with the best effects. As a preventive measure, also, evacuation of the barracks, and encampment at some little distance, is a most useful plan. Before the barrack is re-occupied, every possible means should be taken to cleanse it; sewers should be thoroughly flushed; walls scraped, lime-washed, and fumigated with nitrous acid. If a barrack cannot be altogether abandoned, the ground-floors should be disused. There are several instances in which persons living in the lowest storey have been attacked, while those above have escaped.

5. In all buildings where sick are, or where yellow-fever prevails, there should be constant fumigation with nitrous acid, which seems to be, as far as we know, the best disinfectant for this disease.

6. If it appears on board ship, take the same precautions with regard to evacuations, bedding, &c. Treat all patients in the open air on deck, if the weather permit; run the ship for a colder latitude; land all the sick as soon as possible, and cleanse and fumigate the ship.

*Internal Cause.*—Recent arrival in a hot country has been usually assigned as a cause, but the confusion between true yellow fever and severe febricula (ardent fever or causus) and malarious fevers, renders it uncertain how far this cause operates.† Still, as a matter of precaution, the present plan of three or four years' Mediterranean service before passing to the West Indies seems desirable. Different races possess the peculiar habit which allows the external cause to act in very different degrees; this is marked in the cases of negroes and mulattoes as compared with white men, but even in the European nations it has been supposed that the northern are more subject than the southern nations. Of the sexes, women are said to be less liable than men.

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* Dr Perry (*op. cit.*) considers quarantine useless, and advises a most rigorous system of disinfection. He cites eight instances of the introduction of yellow fever through a strict quarantine, seven to New Orleans and one to Pensacola.

† In the old times in Jamaica it was, however, always noticed that the worst attacks occurred in regiments during the first twenty-four, and especially the first twelve months. In thirteen epidemics in different regiments, four occurred in less than six months after landing, seven in less than twelve months, and two in less than twenty-four months. But it has been stated that residence in one place, though it may secure against the yellow fever of that, does not protect against the disease in another locality. It is much to be wished that all these assertions which abound in books should be tested by figures. That is the only way of coming to a decision.

This predisposition is increased by fatigue,* and it is said, especially when combined with exposure to the sun; by drinking, and by improper food of any kind which lowers the tone of the body.

No prophylactic medicine is known; quinine is quite useless.

Little, therefore, can be done to avert the internal causes, except care in not undergoing great fatigue, temperance, and proper food. The external conditions are the most important to attend to.

### *Dengue.*

This disease, which has attracted much attention of late years, appears to bear some relation to yellow fever, not in its pathological characters, but in the time of its appearance and geographical distribution. It has, however, prevailed in Asia, where yellow fever has hitherto been unknown. In Egypt (according to Vauvray) it is seen at the time of the date-harvest, and is known as "date fever." In other parts of the world it has been attributed to vegetable emanations. Although its symptoms are those of blood-poisoning, it may be doubted if this is due to vegetable emanations only. No preventive is known, but as it is accompanied with an eruption, it would probably be reasonable to deal with it as with other eruptive diseases, such as measles.

### *Cholera.*

*External Cause.*—As in the case of yellow fever, we have no certain clue to the origin of cholera,† and in some respects the propagation of the disease is very enigmatical. The way, for example, in which the disease has spread over vast regions, and has then entirely disappeared,‡ and the mode in which it seems to develop and decline in a locality, in a sort of regular order and at certain seasons, are facts which we can only imperfectly explain.

But as far as preventive measures are concerned, the researches of the last few years seem to have given us indications on which we are bound to act, though they are based only on a partial knowledge of the laws of spread of this poison.

These indications are—

1. The portability of the disease, *i.e.*, the carriage of cholera from one place to another by persons ill with the disease, both in the earliest stage (the so-called premonitory diarrhœa), and the latter period, and in convalescence.§ The carriage by healthy persons coming from infected districts is not so certain; but there is some evidence.|| It is clear this last point is a most

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* Arnold, Bilious Remittent Fever, 1840, p. 82.

† The researches of Lewis and of D. D. Cunningham in India, and of Eberth* of Zürich, have shown that no specific germ has been yet discovered, and have disproved the fungoid and other origins proposed by Hallier, &c.

‡ There is, of course, no doubt that the common autumnal cholera, however much it may resemble superficially the Indian cholera, is quite a separate disease.

§ With respect to convalescence, the only evidence I know of is given by Vols, quoted by Hirsch, Jahresb. für ges. Med. 1868, band ii. p. 221.

|| Especially in the Mauritius outbreaks, where parties of coolies coming from places where cholera prevailed, but being themselves healthy, gave cholera to other parties of coolies who had arrived from India, and had no disease among them. Dr Adams (Army Medical Report, vol. vi. p. 348), in his excellent Report on Cholera in Malta, states, "There are many pointed

* Zur Kenntniss der Bacteritischen Mykosen. Von J. C. Eberth, 1872.

important one, in which it is desirable to have more complete evidence. The occasional carriage by soiled clothes, though not on the whole common, has also evidence in its favour. All these points were affirmed by the Vienna conference of 1874. Even Pettenkofer admitted that man is the carrier of the disease germ, although the *locality* may be the means of rendering it potent. On the other hand, Dr J. M. Cuningham (Ninth Annual Report of the Sanitary Commissioner with the Government of India) makes a *tabula rasa* of everything, denies the transportability of the disease either by persons or by water, and says there is a mysterious factor still to be sought for. His evidence, however, cannot be considered as conclusive.

Whatever may be the final opinion on all these points, we are bound to act as if they were perfectly ascertained. It is usually impossible to have rigid quarantines; *for nothing short of absolute non-communication would be* useful, and this is impossible except in exceptional cases. For persons very slightly ill, or who have the disease in them but are not yet apparently ill, or possibly who are not and will not be ill at all, can give the disease, and therefore a selection of dangerous persons cannot be made. Then as the incubative stage can certainly last for ten or twelve days, and there are some good cases on record where it has lasted for more than twenty, it is clear that quarantine, unless enforced for at least the last period of time, may be useless. The constant evasions also of the most strict cordon render such plans always useless. An island, or an inland village, far removed from commerce, and capable for a time of doing without it, may practice quarantine and preserve itself; but, in other circumstances, both theory and actual experience show that quarantine fails.*

This difficulty, however, of carrying out efficient isolation is no argument against taking every precaution against communication, and keeping a strict watch and control over every possible channel of introduction. In this way, by isolation of the individual, or of bodies of men, as far as possible, and by looking out for and dealing with the earliest case, an outbreak may perhaps be checked, especially by discovering the diarrhœal attacks, and by using disinfectants both to the discharges and to linen.† In the case of troops coming from infected districts, they should be kept in separate buildings for twenty days, and ordered to use only the latrines attached to them, in which disinfectants should be freely used.

2. The introduction of the disease into any place by persons is considered by most observers to be connected with the choleraic discharges, either when newly passed, or, according to some, when decomposing. The reasons for this are briefly these: the portability being certain, the thing carried is more likely to be in the discharges from the stomach and bowels than from the skin

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facts to show that cholera may be introduced and communicated to susceptible persons by healthy individuals from infected districts."

* When circumstances are favourable (as respects trade and intercourse), however, good quarantine may be successful even on the mainland. This was shown in Algeria in 1861. See Dr Dukerley's Notice sur les Mesures de Préservation prises à Batna (Algérie) pendant le Choléra de 1867, Paris, 1868, for a very interesting account of those successful measures of which strict isolation and constant hygienic measures were the principal. So also in America Dr Woodward states (Circular on Cholera, No. 5, Surgeon-General's Office, Washington, 1867) that "the general tenor of Army experience is strongly in favour of quarantine." Quarantine on land was condemned by the Vienna Conference, but recommended on the Red Sea and the Caspian. In Europe, however, only rigorous inspection was recommended, with various rules for preventing spread as much as possible.

† The Indian Government are now cautiously attempting to limit the spread of cholera by superintending and controlling the pilgrimages, which are so common a cause of the spread of cholera in India. The report of the Cholera Committee (Inspector-General Mackenzie, Colonel Silva, and Dr Rankine) to the Madras Government, published at Madras in 1868, gives a great deal of important evidence on this point, and in addition lays down excellent rules for the management of pilgrimages.

or breath (the urine is out of the question), and for these reasons: Water can communicate the disease, and this could only be by contamination with the discharges; water contaminated by discharges has actually given the disease, as in Dr Macnamara's cases; in some cases a singularly local origin is proved, and this is nearly always a latrine, sewer, or receptacle of discharges, or a soil impregnated with choleraic evacuations; soiled linen has sometimes given it, and this is far more likely to be from discharges than from the perspiration; animals (white mice and rabbits) have had cholera produced in them from feeding on the dried discharges. Finally, in the history of the portability of cholera, there are many instances in which, while there has been decided introduction by a diseased person into a place, there has been no immediate relation between that person and the next case; in other words, the cause must be completely detachable from the first case, and must be able to act at a distance from his body; it is therefore far more probable that the discharges are this carrying agency, than that any effluvia should pass off from the lungs and skin which could spread to a great distance.

Enough has been said to show that the discharges must receive the most careful attention. Every discharge ought to be disinfected with strong substances liberally used; the best are carbolic acid (in large quantity), perchloride of iron, chloride of zinc, chloride of lime, or, if none of these are at hand, good quicklime (see DISINFECTANTS). Although the results of disinfection of the discharges have not hitherto been encouraging, the plan has seldom been completely tried. All latrines should be disinfected, sewers flushed, carbolic acid poured down them, and every means taken to keep them ventilated.

What should be done with the disinfected discharges? Should they be allowed to pass into sewers, or buried in the ground? They must in some way be got rid of. Sewers certainly afford an easy mode of disposing of them; and as the discharges are mixed with much water, and are rapidly swept away in them, and as the temperature of the sewers is low, and decomposition is delayed, it is quite possible that sewers may be a means of freeing a town from choleraic discharges more easily than any other plan. And it appears to be a fact, that in the well-sewered towns in England the cholera of 1865 and 1866 never attained any wide spread. In large towns, also, there are no other means of disposing of the discharges. But may not sewers be a means of dissemination,* and thus, as in some outbreaks of enteric fever, be a source of danger? And again, when sewerage is poured over land, as it will be soon throughout all England, are we quite sure that no choleraic effluvia will pass off, or that the choleraic particles passing into the ground may not develop there, as Pettenkofer supposes is the case? I know of no facts to enable us to decide, and I do not think we ought at present to form an opinion on the probability of mischief arising in this way, but it should, at any rate, make us still more urgent in the use of disinfectants to all discharges.

Again, as to disposal in the earth, if Pettenkofer is correct, a loose moist earth is the place where the supposed germ of cholera acquires its power. The last place we should put a choleraic discharge would be the earth; and there would be even an argument against the use of the earth plan of dealing with sewage. Still, as there is much to be said against Pettenkofer's views, and as in small towns and villages there is only the alternative of allowing the discharges to pass into cesspools or streams, or to be disposed of in the earth, I think the safest course is to deeply bury all disinfected discharges, care being taken to place them at a distance from houses and from sources of water supply.

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* That these may be so, in a particular way, I have rendered probable in my Report on Cholera in Southampton (Sixth Report of the Medical Officer to the Privy Council, p. 251); but still there is very little evidence on this point.

That linen and bedding should be carefully disinfected, needs no argument (see chapter on DISINFECTION). In some English towns all cholera clothing has been burnt, but whether this measure is necessary or not is uncertain. But thorough steeping and boiling before washing is essential, as washerwomen have certainly suffered in many cases.

3. The introduction of the agent by the medium of the air is generally admitted, on the plea that cases occur in which any other mode of entrance is impossible. It is also held by some that, existing in the air it can be carried for great distances by winds; and some observers indeed believe this to be its usual mode of transit, though this opinion appears to me opposed to all we know of its spread.

Without attempting to decide the point or to state the limits of the transmission, it is a matter of prudence to act as if the winds did carry the poison. The Indian rule is to march at right angles to the wind, and never against it or with it if it can be avoided. The spreading by the winds in India has been usually ascribed to the custom of throwing all the cholera evacuations on the ground; there they get dried, and then are lifted by the wind and driven to other parts. This seems probable, but no decided proof has been given; and an argument against it may be raised on the difficulty of accounting for the immunity of adjacent places if such transmission were common. So also the use of aerial disinfectants in cholera is rendered imperative by the chance that the cause may be in the air. The Vienna Conference affirmed transmission by the air, but only to a short distance, and never faster than man travels. They also recognised the great safeguard afforded by deserts, as the disease has never been known to be imported into Eygpt or Syria across the desert by caravans from Mecca.*

4. The occasional, perhaps frequent, introduction by water seems certain. It was unanimously affirmed at the Vienna Conference, even by Pettenkofer. It is a good plan always to change the source of supply, to use rain water if no other fresh source is procurable; and in every case to boil, and filter through animal charcoal, and to use also potassium permanganate.† It remains yet uncertain whether a water which gives cholera is always chemically impure, or whether the choleraic matter may be in so small a quantity as to be absolutely indetectable. In the two cases I have examined in which the water was the cause, it was highly impure. In India it is now ordered that all the water should be boiled. (G. O. C. C. No. 192, Clause 53.)‡

5. The introduction by food has been noted in some cases (although the Vienna Conference decided, by 11 to 7, that present facts do not warrant a

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* On this point the history of Chili is interesting, as cholera has never reached it. It is separated on the north from Peru by the desert of Attacama, and from the Argentine Confederation on the east by the Andes range, to which circumstances its immunity hitherto from epidemic diseases has been ascribed by the inhabitants.

† In the very able Report on Epidemic Cholera in the United States Army (Circular No. 5, War Department; Surgeon-General's Office, Washington), is what appears to be a good instance of the effect of changing the supply. At New Orleans rain, and in some cases distilled water, was supplied instead of river water, with the apparent effect of checking the spread (p. xvii.); see also the cases of Utrecht and Rotterdam, as reported by Buys-Ballot.

‡ Förster of Breslau (Die Verbreitung der Cholera durch die Brunnen, 1873) urges two recommendations which he thinks will prevent cholera in the future—1st, Lead to every town, even if at great cost, abundant and pure water, as indeed was done, he says, much better 2000 years ago than now. 2d, Protect the ground from contamination in any way from excrements, and banish all cesspits. The ground must be absolutely pure, and this can only be if all faecal matter is removed to a distance.

decision). Every article of food, solid and liquid, should therefore be passed in review, and the cooking arrangements gone over step by step.*

6. The localisation of cholera is a marked feature in its history.† It is often as marked as in yellow fever, and may be confined to a very small area. At other times, in India, the "tainted district" may be of some extent. From this fact of localisation arises the important rule of always leaving the locality when practicable, and in a large town of clearing out the house where cholera has happened. In India the present rule is to march the men and encamp in a healthy spot at some little distance, changing the encamping ground from time to time. On the whole, this has acted well, and should be adhered to, though occasionally it has failed, generally, however, I believe, from error in choice of locality. The men should be tented; the tents should be well ventilated, and often struck and repitched; an elevated spot should be chosen, and damp and low soils and river banks avoided. Orders lay down with precision the exact steps to be taken by a regiment when cholera threatens.‡ This rule of marching out must, of course, be subject to some exceptions. It has been advised that it should not be done in the rainy season in India. This must depend on the locality. I have been informed that it has sometimes answered well, even in heavy rains; but in other cases the rains may be too heavy. No absolute rule can be laid down; but the circumstances which are allowed to set aside the grand rule of evacuation of a tainted place should be unequivocal.

In connection with change of locality, the opinions of Pettenkofer should be borne in mind. Pettenkofer believes that, of all conditions, the effect of soil is the most important. It is necessary, then, to consider particularly the nature of the soil where the fresh camps are to be placed, and to select the perfectly dry and, if possible, pure, impermeable, uncontaminated soils, and to prevent the cholera discharges from percolating through the ground.

7. Men sick from cholera are also best treated in well-ventilated tents, whenever the season admits of it. Even in cold countries, up to the end of October or the middle of November, tents can be used if properly warmed. In India it should be a rule to treat every cholera patient in a tent, as far as circumstances permit it.

*Internal Causes.*—General feebleness of health gives no predisposition, nor is robust health a safeguard; some even have thought that the strongest men suffer most. Great fatigue, and especially if continued from day to day, greatly predisposes; of this there seems no doubt.§ No certain influence has yet been traced to diet, although it has been supposed that a vegetable diet and alkalinity of the intestinal contents may predispose. It does not appear that insufficient diet has any great effect, though there is some slight evidence that scurvy increases the mortality, and perhaps the predisposition.[*] The strictest temperance does not preserve from attacks; but every one agrees that spirits are no protection, and that debauchery increases liability.

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* See Dr Fairweather's Delhi case in the Sanitary Report of the Punjab for 1871; also given in my Report on Hygiene, in the Army Medical Report, vol. xiii. (1873).

† Surgeon P. Cullen (Indian Medical Gazette, 1st July 1873), notices a very singular case of localisation at Etarsi.

‡ The order in India is, if a single case occur in a barrack, to vacate that part of the barrack, and to encamp the men in the cantonment. If a second case occur among the body of men thus removed, they are again moved, and the building or tent is vacated and purified. If a third case occur in this body of men within a week, they are removed to the preparatory camp.

Buildings are purified by scraping and washing walls with hot caustic limewash; boiling punkah fringes, ropes, curtains, &c., and using chloride of lime or other disinfectant. Tents are purified by being fumigated with either chlorine, nitrous acid, or sulphurous acid, and then exposed to the weather for ten days. Railway carriages, after occupation by troops carrying cholera, are purified by washing with boiling water containing in each gallon a wineglassful of carbolic acid, and burning sulphur in the closed carriages for two hours. If troops are moved by rail, they are not to use latrines, but trenches are to be dug for them (G. O. C. C.), No. 193.

§ There are many instances of the effects of long marches. See Orton, Lorimer, and Thom quoted in Brit. and For. Med. Chir. Rev., July 1848, pp. 55-57.

Of pre-existing diseases, it has been supposed that cardiac affections and pulmonary emphysema predispose; the evidence is very unsatisfactory. If Beale's observations be correct, post-mortem examinations often show previous affection of the villi and mucous membranes of the intestines generally; but it is very desirable there should be more proof of this.

Diarrhœa predisposes, and any causes which lead to diarrhœa, especially impure water, dietetic errors, &c., should be carefully looked after.

With regard to prophylactic measures (except in respect to proper diet, free ventilation, and pure water) nothing has been yet made out. Quinine has been recommended, and should certainly be given, especially in malarious countries, as it is a fact that the choleraic poison and malaria may act together, and even give a slight periodical character to choleraic attacks, which is never seen in non-malarious districts, and is therefore merely grafted on cholera. Peppers, spices, &c., have been used; but I am not aware of any good evidence. All diarrhœa should be immediately checked, and this is well known to be the most important point connected with the prevention of the internal causes. The universal order in India is, that any man going twice in one day to the latrine should report himself; and non-commissioned officers are usually stationed at the latrines to watch the men. The reason of this rule should be fully explained to the men. In two attacks of cholera in India, I found it almost impossible to get the men to report themselves properly; the slight diarrhœa of early cholera is so painless that they think nothing of it.[†] In England and Germany house to house visitation has been found very useful.[‡]

### *Typhus Exanthematicus* (*Spotted Typhus*).

*External Cause.*—An animal poison, origin unknown, but communicable from person to person, probably through the excretions of the skin and lungs floating in the air. Not known to be communicated by water or food. Its spread and its fatality are evidently connected with overcrowding and debility of body from deficient food. That it can be produced by overcrowding is yet uncertain.* The preventive measures may be thus shortly summed up:—Adopt isolation† of patients; use the freest ventilation (5000 to 6000 cubic feet per head per hour or more); evolve nitrous acid and chlorine fumes; thoroughly fumigate with sulphurous acid, heat (to 240° Fahr.),‡ wash, and expose to air all bedding (including mattresses) and clothes. This last point is extremely important. In fact, it may be said that, for the prevention as well as treatment of typhus, the cardinal measures are abundance of pure air and pure water. Whenever practicable, treat all typhus patients in tents, or wooden huts with badly-joined walls, not in hospitals. Fumigate tents and scrape and limewash huts, and remove earth from time to time from the floors. A number of typhus patients should never be aggregated; they must be dispersed; and if cases begin to spread in an hospital, clear the ward, and then, if the disease continues, the hospital itself; then wash with chloride of lime, and then limewash or scrape walls and floors, and thoroughly fumigate with nitrous acid. It has been often shown that even exposure to weather, bad diet, and insufficient attendance, are less dangerous to the patients than the aggregation of cases of typhus (see especially p. 353).

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[*] For some evidence as to scurvy, see Pearce and Shaw on the Cholera of the jail at Calicut.—*Madras Medical Journal*, July 1868.

[†] I have taken several points from Mr Dickinson's useful little pamphlet on the Hygiene of Indian Cholera, 1863.

[‡] Great importance has been attached to the meteorological condition attending outbreaks of cholera; they do not appear to be very important, except in two or three cases.

1. *Temperature.*—A high temperature favours the spread by increasing the putrefaction of the stools, and by augmenting generally the impurity of the air. When cholera has prevailed at a low temperature (it has been severe at a temperature below freezing), the drinking water has possibly been the cause.

2. *Pressure* has no effect. The old observation of Prout, that the air is heavier in cholera epidemics, has never been confirmed.

3. *Moisture in Air.*—Combined with heat, this seems an accessory cause of importance probably by aiding transmission. Moisture in the ground, combined with heat of the soil, has always been recognised as an aiding cause of great importance.

4. *Dryness of Air* seems decidedly to check it.

5. *Rain* sometimes augments, sometimes checks it. This, perhaps, depends on the amount of rain, and on whether it renders the drinking water more or less pure. A very heavy rain is a great purifier.

6. *Movement of Air.*—It is certainly worst in the stagnant atmospheres, as in the cases of all the specific poisons.

7. *Electricity* is not known to have any effect. This was particularly examined by Mr Lamont in Munich, one of the most celebrated physical philosophers of our time, but with entirely negative results.

8. *Ozone* has no effect, either in its presence or absence. (Schultze, Voltolini, De Wethe, Lamont, Strambio, Wunderlich.)

*Internal Causes.*—A special condition of body is necessary, as in the case of smallpox, and one attack protects to a great extent from another. The nature of the internal condition is unknown; but general feebleness from bad diet, overwork, exhaustion, and especially the scorbutic taint, greatly increase the intensity of the disease in the individual, and perhaps aid its spread. These conditions, then, must be avoided. But the strongest and best health is no guarantee against an attack of typhus.

### *Bubo or Oriental Plague (Pali Plague in India).*§

The preventive measures should be the same as in typhus, to which this disease shows great analogy. The history of the plague at Cairo (from which it has been now banished for many years, simply by improving the ventilation of the city),‖ and the disappearance, after sanitary improvements, of the Pali plague in India, and its recurrence on the cessation of preventive measures, show that, like typhus, the bubo plague is easily preventible. Elevation, as in so many other specific diseases, has a considerable effect; the village of Alum Dagh, near Constantinople (1640 feet above the sea), and freely ventilated, has never been attacked; the elevated citadel of Cairo has generally been spared; and when Barcelona was attacked, the elevated citadel also escaped.

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* During the French war of 1870, although there was much crowding, wretchedness, and misery in Paris, and particularly in Metz, there was but little typhus; it was nothing like the amount in the first Napoleon's time (Grellois, Histoire Médicale du blocus de Metz, 1872, Chauffard, Académie de Médicine.)

† By the term isolation, I imply the placing a patient in a separate building, not in another room in the same building; in the case of smallpox, typhus, and scarlet fever, this partial isolation, though sometimes successful, cannot be depended upon. If a room must be chosen in the same building, choose the top story, if a room can be there found.

‡ This temperature is perhaps higher than necessary: recent experiments have shown that there is great danger of charring at so high a temperature.

§ The Pali plague (Maha Murree), which was most common in Rajpootana, was evidently propagated by the filthy habits of the inhabitants (see Ranken and others), and was some years ago almost entirely got rid of by sanitary measures. Subsequently, these were neglected, and the disease returned. It is now, I believe, again greatly lessened. Hirsch has pointed out that the Pali plague differs from the Egyptian plague, in having a marked lung disease, and in this it resembles the black death in the fourteenth century, with which Hirsch, in fact, considers it identical.

‖ Stamm, in Pappenheim's Beiträge, 1862–3, p. 30. The measures adopted in Cairo were levelling some hillocks, which stopped the air from blowing over the city, filling up some marshes, and adopting a better mode of burial. The peculiar sepulture customs of the Copts have indeed even been assigned as the sole cause of the origin of plague.

### *Typhoid or Enteric Fever.*

*External Cause.*—A poison of animal origin; one mode of propagation is by the intestinal discharges of persons sick of the disease; other modes of origin and transmission are not disproved. There is doubtless a frequent transmission of the disease by the diarrhœa of mild cases which are often not diagnosed. There is some evidence that persons considered convalescent may carry the disease,* but it is possible that this may have been owing to badly washed clothes. The mode of entrance into the body is both by air and water. (See pages 47 and 127).) Entrance by food (milk) has been lately also proved. As means of arresting the disease, isolate the patients; receive all evacuations (fæces and urine) into the vessels strictly kept for one sick person; place zinc chloride, or ferrous sulphate, or carbolic acid, &c., in the vessels; never empty any evacuation into a closet, sewer, or cesspool; bury it several feet deep, and mix it well with earth. Fumigate, and heat to 240°† Fahr., all clothes and bedding. Use nitrous acid fumes in the wards. As means of prevention, attend especially to the purity of the drinking water, and to the disposal of sewage; although the origin of typhoid merely from putrefying non-typhoid sewage is not considered at present to be probable, it is not disproved, and it is certain that the disease may spread by the agency of sewers and fæcal decomposition. A single case of typhoid fever should at once be held to prove that something is wrong with the mode of getting rid of the excretions. If neither water nor sewers can be proved to be in fault, consider the milk and other food supply.

*Internal Causes.*—As a first attack preserves in a great measure from a second, a peculiar condition of body is as essential as in smallpox; and looking to the special effect produced on Peyer's patches, and to the fact that at the period of life when these patches naturally degenerate, the susceptibility to typhoid fever materially lessens, or even ceases, it seems possible that the internal cause or necessary second condition is the existence of these patches, the structures in which are brought into an abnormal state of activity by the direct or indirect action of the poison on them. The other internal causes are anything which causes gastro-intestinal disorder, such as bad water, and general feebleness.

### *Relapsing Fever.*

No preventive measures have been yet pointed out, to my knowledge, but the occurrence of the disease in times of famine seems to indicate that feebleness and inanition are necessary internal causes.

### *Bilious Remittent Fevers.*

Under this vague term, a disease or diseases, which in many points are like relapsing fever, but yet are not identical (Marston), have been described as occurring especially in Egypt (Griesinger), and in the Levant generally. It has been lately described by Drs Marston and Boileau‡ at Malta. The exact causes are not known; but in some of the writings of the older army surgeons, the fevers which are produced by foul camps (in addition to typhoid) appear to have a close resemblance to the bilious remittent fevers of the Mediterranean. They appear to be connected with bad sanitary conditions, but their exact causation is not clear.

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* Gietl. Die Ursachen der enterischen Typhus in München, 1865, pp. 74 and 94.

† Probably 220° would be sufficient if the temperature reached every part. See under DISINFECTION.

‡ Army Med. Reports, vols. iii. and viii.

### *Cerebro-Spinal Meningitis.*

This disease, which has occasionally been noticed in France, and especially among soldiers for the last forty years, has within the last few years appeared in several parts of Germany, and a few cases among civilians have occurred in England. It seems to depend on a specific agent, but very little is yet known about it. It does not appear to be contagious. No preventive measures can be at present suggested.

### *The Eruptive Fevers.*

The method of employing disinfectants in these diseases is noted in the chapter on DISINFECTANTS.

Smallpox is guarded against in the army by repeating vaccination in the case of recruits, and by occasional re-vaccination of all the men in a regiment. In Dr Balfour's statistical reports, great attention is always paid to this important point, and the evidence from foreign armies prove the necessity of careful re-vaccination.

If the disease does occur, the use of chlorine, iodine, and nitrous acid thrown up into the air, should not be forgotten, in addition to all usual measures of isolation[*] (in separate buildings) and sanitary appliances.

In the case of scarlet fever and measles, nothing definite is known with regard to prevention, except that a good sanitary condition seems to lessen their intensity, and probably their spread. The evidence with regard to belladonna in scarlet fever is contradictory, but on the whole unfavourable. When the disease is actually present, fumigations, as in smallpox, should be used. All the discharges should be disinfected, and the skin well rubbed over with camphorated oil and a little weak carbolic acid.

The most difficult case is when either measles or scarlet fever appears on board ship, and especially if children are on board. If the weather permit, the best plan is then to treat all patients on the upper deck under an awning. If this cannot be done (and scarlet fever patients must not be exposed to cold), they must be isolated as much as possible, and the place constantly fumigated. Both in scarlet fever and smallpox there is some evidence to show that the incubative period may be very long.[†]

Perhaps, in the present state of evidence, it might be desirable to try the prophylactic effects of belladonna on board ship, directly the first case occurs.

### *Erysipelas (Hospital or Epidemic).*

*External Cause.*—It is well known that in the surgical wards of hospitals erysipelas occasionally occurs, and then may be transmitted from patient to patient. The exact causes of its appearance have not been made out, but it is evidently connected with overcrowding and impure air. Moisture of the floors, causing constant great humidity of air, has also been supposed to aid it. It is much more common in fixed hospitals than in tents and huts, and indeed is exceedingly rare in the two latter cases. The agencies or agent can scarcely be supposed to be other than putrefying organic matter and pus cells passing into and accumulating in the air.[‡] They or it would appear to be really generated during the process of suppuration of wounds, and at present the production of a transmissible agent in this way is one of the best examples we have of the origin of a contagion *de novo.* It is remarkable that pus cells derived from purulent sputa do not cause erysipelas in medical wards, but this may be from a want of open wounds to give the necessary personal condition.

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[*] Buchanan gives a good example of the advantages of isolation in the case of Cheltenham, where smallpox was introduced into the town six times, but, in consequence of proper hospital accommodation for *all* classes, never made good its footing.

[†] See a case by Bryson (Trans. Soc. Science Assoc. 1862, p. 677), *for a case in which the* incubative period of smallpox was thirty-one days. In scarlet fever it is sometimes even longer.

[‡] See page 161.

When hospital erysipelas has once appeared in a ward, nothing will avail except complete clearance of the ward, scraping the floors, and often the walls, washing with chloride of lime, and then with solution of caustic lime, and thorough fumigation with chlorine and nitrous acid alternately. The erysipelatous cases should be placed in well-ventilated tents. If this cannot be done, then nitrous acid and chlorine fumigations must be constantly used in the wards, charcoal trays be placed round the bed of the erysipelatous patient, and excessive ventilation employed.

Considering the undoubted beneficial influence of tent life, it may be a question whether, even in civil life, hospitals which possess gardens should not, during the summer, treat their surgical cases with suppurating wounds in the tents.* In many continental towns the large hospitals have now wooden barrack-like huts attached to them, in which the surgical cases are treated.

Of course, extreme care in conservancy of wards or tents, the immediate removal of all dressings, great care in dressing wounds, so that neither by instruments, sponges, lint, or other appliances, pus cells or molecular organic matter shall be inoculated, are matters of familiar hospital hygiene. The use of carbolic acid, as introduced by Professor Lister, will, it is hoped, greatly lessen the chances of spread in the case of erysipelas as well as of hospital gangrene.†

*Internal Causes.*—Nothing, I believe, is known on this point, except that there must be some abrasion or wound of the surface or of the passages near the surface, as the vagina or throat. The erysipelas commences at the point of abrasion. If there is no open wound, the atmospheric impurity seems to have no bad effect on the persons who are exposed to it, but it would be interesting to know if some forms of internal disease are not produced. Is it possible that some forms of tonsillitis and diphtheritic-like inflammation of the throat may be caused in this way, although there is no solution of continuity?

### *Hospital Gangrene.*

Almost the same remarks apply to hospital gangrene as to erysipelas. One of the most important facts which has been pointed out by many writers, and which has been thoroughly proved by the American and the Italian wars, is that perfectly free ventilation prevents hospital gangrene. Hammond, the late Surgeon-General of the United States Army, declares‡ that only one instance has come to his knowledge in which hospital gangrene has originated in a wooden pavilion hospital, and not one which has occurred in a tent. Kraus also, from the experience of the Austrians in 1859, states that it never could be discovered that gangrene orginated in a tent. On the contrary, cases of gangrene at once commence to improve when sent from hospital wards into tents. On the other hand, the tenacity with which the organic matters causing the gangrene adhere to walls is well known.

The measure to be adopted in wards when hospital gangrene occurs, and the ward cannot be at once evacuated, are the same as for erysipelas.[*] It is not necessary to do more than allude to the undoubted transference by dirty sponges, &c., and to the beneficial effects of carbolic acid dressings.

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* See Hammond's Hygiene, 1863; Kraus' Das Kranken und Zerstreuungs-System, 1861; and a Report on Hygiene, by the author, in the Army Medical Report, for 1862, for the effects of tents on erysipelas and hospital gangrene.

† I was informed, in Munich, that Lister's system has completely banished hospital gangrene from that city, and I believe the same result has been noticed in other German towns. (F. de C.)

‡ Hygiene, p. 297.

## SECTION II.

## VARIOUS NON-SPECIFIC DISEASES.

### *Dysentery and Diarrhœa.*

At present there is no evidence that the dysentery arising from various causes has different anatomical characters, or runs a different course, except perhaps in the case of malarious dysentery. The chief causes are—

1. *Impure Water* (p. 42).—Both Annesley and Twining have directed attention to this cause, in their accounts of Indian dysentery. It is scarcely possible that, with common attention, this cause should not be discovered and removed.

2. *Impure Air.*—The production of dysentery and diarrhœa from the effluvia of putrefying animal substances is an opinion as old as Cullen, and probably older ; and there seems little doubt of its correctness. The gases and vapours from sewers also will, in some persons, cause diarrhœa (pages 127, *et seq.*) ; and also effluvia from the foul bilge-water of ships.[†] On the other hand, very disagreeable effluvia from many animal substances, as in the case of bone-burners, fat-boilers, &c., do not seem to cause diarrhœa. In India there appears to be a decided relation between the prevalence of dysentery and overcrowding and want of ventilation in barracks ; massing a large number of men together is certainly an accessary cause of great weight.[‡]

The air from very foul latrines has caused dysentery in numerous cases. Pringle, and many other army surgeons, record cases.[§] In war this is one of the most common causes. The occasional production of dysentery from sewage applied to land, seems to me to be proved by Clouston's observations on the causes of the attack of dysentery in the Cumberland Asylum (*Medical Times and Gazette*, June 1865). Still sewage matter has been often applied in this way without bad effects. In Dr Clouston's case the sewage was 300 yards from the ward where the dysentery occurred. Calm and nearly stagnant nights, or with a *gentle* movement of air from the sewage towards the ward, were the conditions which preceded most of the attacks.

Of all the organic effluvia, those from the dysenteric stools appear to be the worst. Some evidence has been given to show that dysentery arising from a simple cause (as from exposure to cold and wet), when it takes on the gangrenous form, and the evacuations are very fœtid, produces dysentery in those who use the latrines, or unclean closets, into which such gangrenous evacuations are passed. If correct, this is a most interesting point, as it seems to show the origin of a communicable poison *de novo*. Possibly, in all these cases, effluvia, or organic matters, or particles disengaged from the putrefying evacuations, act at once on the anus, and the disease then spreads up by continuity.

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[*] With regard to pyæmia, observations show that one of the external causes is fœtid organic emanations. Spencer Wells (Med. Times and Gazette, 1826) states, that in 1859 the mortality from pyæmia was great in some wards over a dissecting room. On removing all the cases after operation to the opposite side of the building, pyæmia almost disappeared. Other similar cases are on record.

[†] Fonssagrives (Traité d'Hygiène Navale, p. 60) records a good case of this kind. It commenced after a gale at sea had stirred up the bilge, and on clearing it out the attack ceased.

[‡] Wood on the Health of European Soldiers in India, 1864, p. 45, *et seq.*

[§] Sir James M'Grigor, Vignes (who gives many cases from the French experience in the Peninsula), Chomel, Copland ; see also the Dic. des Sciences Méd. Art. *Dysentérie.* D'Arcet (Ann. d'Hygiène, vol. xii. p. 390) records a good case, in which a whole regiment was affected in the Hanoverian war, from having used too long the same trench as a latrine. The disease disappeared when another was dug.

There is some reason, also, to think that retaining dysenteric stools in hospital wards spreads the disease ; and, perhaps, in this case, the organic particles floating up may be swallowed, and then act on the mucous membrane of the colon. In the epidemic of dysentery in Sweden in 1859, there was good evidence to show that it spread by means of the diarrhœal and dysenteric evacuations.[*]

In addition to removal of the sources of all these effluvia, fumigations with nitrous acid and with chlorine should be practised in all dysenteric wards as in the case of typhoid fever, the stools must be mixed with disinfectants, and immediately removed from the wards and buried.

3. *Improper Food.*—Any excess in quantity, and many alterations in quality (especially commencing decomposition in the albuminates, and, perhaps, the rancidity of the fatty substances) cause diarrhœa, which will pass into dysentery (see the chapter on FOOD). But the most important point in this direction is the production of scorbutic dysentery. A scorbutic taint plays a far more important part in the production of dysentery than is usually imagined, and there is now no doubt that the fatal dysentery, which formerly was so prevalent in the West Indies, was of this kind. Much of the Indian dysentery is also often scorbutic.

4. *Exposure to Cold and Wet.*—Exposure to cold, especially after exertion, and extreme variations of temperature, have been assigned as the chief cause of dysentery by numerous writers ;[†] great moisture has been assigned by some writers (Twining, Annesley, Griesinger) as a cause ; and great dryness of the air by others (Mouat) ; while a third class of observers have considered the amount of moisture as quite immaterial.

Hirsch,[‡] after summing up the evidence with respect to temperature with great care, decides that sudden cold after great heat is merely a "*causa occasionalis*"[§] which may aid the action of the more potent cause of dysentery. This, probably, is the true reading of the facts. The amount of moisture in the atmosphere would appear to be a matter of no moment.

Although we cannot assign its exact causative value, the occurrence of chill is, of course, as a matter of prudence, to be carefully guarded against ; and especially chills after exertion. It is when the body is profusely perspiring, and is then exposed to cold, that dysentery is either produced, or that other causes are aided in their action. In almost all hot countries chilling of the abdomen is considered particularly hurtful, and shawls and waist-bands (kummerbund of India) are usually worn.[||]

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[*] British and Foreign Med.-Chir. Rev. Jan. 1866, p. 140.

[†] A few only can be noted ; Stoll, Zimmermann, Huxham, Durandeau, Willan, Irvine, James Johnson, Annesley, Bampfield, Morehead, Vignes, Fergusson, &c. Fergusson says—"True dysentery is the offspring of heat and moisture ; of moist cold in any shape after excessive heat. Nothing that a man can put into him would ever give him true dysentery."

[‡] Handbuch der Historisch-Geograph. Pathol. band ii. p. 234.

[§] The so-called "hill diarrhœa," which was formerly prevalent on some of the hill sanitaria in India, especially on the spurs of the Himalayas, has been attributed to the effect of cold and moisture, and sudden changes of temperature. But, as remarked by Dr Alexander Grant, many hill stations have these atmospheric conditions without having any hill diarrhœa. I learn from some gentlemen who have paid much attention to this subject, that there is great reason to suppose the hill diarrhœa to be entirely unconnected with either elevation or climate. In some cases it has been clearly caused by bad water, possibly by suspended scales of mica in the water (see page 40) ; in other cases, its exact causes remained unexplained. Of late years it has lessened in amount at all stations, and will probably disappear.

[||] It is a remarkable circumstance, that in temperate climates the most common months for dysenteric epidemics are the hot months—June to September. Taking North America and Northern and Western Europe, Hirsch has assembled 546 outbreaks. Of these, 176 occurred

5. Malaria has been assigned as another cause; and it was noticed, especially by the older writers, that the dysentery was then often of the kind termed "*Dysenteria Incruenta*"—the stools being copious, serous, and with little blood; in fact, a state somewhat resembling cholera.

Very great difference of opinion has prevailed in regard of this opinion.[*] Possibly the "malarious dysentery" is in part connected with the use of marsh water. More evidence is desirable, certainly, with regard to this point; but it seems probable, from the observations of Annesley and Twining, that marsh water has an effect in this direction.

## *Liver Diseases* (*Indian*).

The production of diseases of the liver is so obscure, and so many states of hepatic disorder are put together under the term "hepatitis," that it is impossible to treat this subject properly without entering fully into the question of causes. But, as this could not be done here, I must content myself with a short summary of the preventive measures which appear to be of the greatest importance.

I have long been convinced that many cases of hyperæmia, bilious congestion, and enlargement of the liver, with increase of cell-growth and connective tissue (but without tendency to abscess), and enlargement and partial fatty degeneration of the liver cells, are caused simply by diet.[†] I had a good opportunity of observing this on landing in India in 1842 with an European regiment,[‡] and the experience of more than twenty years has made me certain that the observation was correct.

Very similar opinions have been expressed by Macnamara,[§] and Norman Chevers has also pointedly alluded to this subject.[‖]

The supply of food supplied to the soldier in India has erred in two ways: it is too much in quantity, especially when the amount of exercise is limited. Macnamara has calculated that each European soldier in Bengal consumed (at the time he wrote in 1855) 76 ounces of solid (*i.e.*, water containing) food daily, so that there must have been an excess of all the dietetic principles. Then, in every case, there was added to this a very large amount of condiments (spices and peppers), articles of diet which are fitted for the rice and vegetable diet of the Hindu, but are particularly objectionable for Europeans. In the West Indies, where the diet has never been so rich in condiments, liver diseases have always been comparatively infrequent.

Some orders for improving the cooking in India were issued by Lord Strathnairn, and if these are carried out, and if medical officers would thoroughly investigate the quantity of food taken by the men, and compare it with their work, and examine into the cooking, it is quite certain that many cases of dyspepsia and hepatitis would be prevented.

In cases not simply of hyperæmia and bilious congestion, but of abscess, it is probable that a certain number are consecutive to dysentery, and are caused

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in summer; 228 in summer and autumn; 107 in autumn; only 16 in spring; and 19 in winter. This does not look as if cold had any effect. The heat of summer is far more influential.

[*] The very varying opinions are given very fully by Hirsch. Morehead's great authority is altogether against the presumed action of malaria; but possibly here, as in many other cases, we shall have to draw a complete distinction between malarious and non-malarious dysentery.

[†] In the great and admirable works of Ranald Martin and Morehead, the influence of diet in producing liver affections, though alluded to, has been passed over much too lightly. Annesley, on the other hand, has fully recognised the immense influence of diet (vol. i. p. 192).

[‡] Remarks on the Dysentery and Hepatitis of India, by E. A. Parkes, M.B., 1846, p. 228.

[§] Indian Annals, 1855. Dr Macnamara found a most extraordinary amount of fatty degeneration of the liver.

[‖] Health of European Troops in India, Indian Annals, 1858, p. 109; it is particularly recommended that this chapter should be carefully perused.

Under this convenient term, a number of cases are put together which seem to be produced by one or more of the following causes:—

*External Causes.*—1. Direct rays of the sun on the head and spine. Adopt light coverings, covered with white cotton; permit a good current of air between the head and the covering, and use a light muslin or cotton rag, dipped in water, over the head under the cap. 2. Heat in the shade, combined especially with stagnant and impure air. In houses (and men have been attacked with insolation both in tents and barracks) means can always be taken to move the air, and thus keep it pure, even if it cannot be cooled. In tents the heat is often exceedingly great, simply from the fact that there is not sufficient movement of air; in the tropics a simple awning is much better than tents, and if the awning is sloped a little, the top of the slope being towards the north, the movement of air will be more rapid than if the canvas be quite flat. But in the dry season, in the tropics, the men should sleep in the open air in all non-malarious districts, when they are on the march or in campaigns.

The general prophylaxis has been thus summed up by Professor Maclean ("Reynolds' System of Med.," vol. ii. p. 157):—"Men will bear a high temperature in the open air with comparative impunity, provided (*a*) it is not too long continued; (*b*) that the dress be reasonably adapted to the temperature; (*c*) that the free movement of the chest be not interfered with."

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* It is, however, remarkable how many cases of dysentery occur without producing hepatic abscess; still our general knowledge of the causation of disease makes it highly probable that dysentery acts in this way. Is it the sloughing dysentery which is followed by hepatic abscess?

*Internal Causes.*—It is only known that spirit drinking, even in moderation, powerfully aids the external causes of insolation; even wine and beer probably have this effect. Tea and coffee, on the other hand, probably lessen the susceptibility.

A full habit of body, or any tendency to fatty heart or emphysematous lungs, have been supposed also to predispose.

It seems certain that any embarrassment of the pulmonary circulation aids the action of the heat, and therefore the most perfect freedom from belts and tight clothes over the chest and neck is essential.

Great exhaustion from fatigue aids the action, either from failure of the heart's action or want of water. In this case diffusible stimuli, such as ammonia, tincture of red lavender, tincture of cardamoms, &c., with strong coffee, are the best preventives. Spirits should not be given unless the exhaustion be extreme, and the diffusible stimuli cannot be obtained. A small quantity in hot water may then be tried.

Cold baths, and especially cold douching to the head and spine, are most useful as preventive as well as curative measures.

### *Phthisis Pulmonalis.*

In respect of causes, we must distinguish those usually rapid cases of tuberculosis which arise from hereditary constitutional causes, or from the influence of exanthemata (especially measles), or of typhoid, or other fevers, and which run their course with implication of several organs at an early stage, and the more chronic forms of phthisis, in which the lung in adults is the first seat of the disease, and other organs are secondarily affected. Several distinct diseases are confounded under the one term of phthisis, and it is therefore not possible at present to trace out their precise origin.

Taking only the common cases of subacute or chronic phthisis, it has been already intimated that most European armies have been found to furnish an undue proportion of such cases.*

A few years ago much influence was ascribed to food as a cause of phthisis; the occurrence of a sort of dyspepsia as a forerunner (though this does not seem very common), and the great effect of the treatment by diet (by cod-liver oil), seemed to show that the fault lay in some peculiar malnutrition, which affected the blood, and through this the lungs.

Probably there is truth in this; but of late years the effects of conditions which influence immediately the pulmonary circulation and the lungs themselves have attracted much attention. The effect of want of exercise (no doubt a highly complex cause, acting on both digestion and circulation), and of impure air, have been found to be very potent agencies in causing phthisis, and conversely, the conditions of prevention and treatment which have seemed most useful are nutritious food and proportionate great exercise in the free and open air. So important has the last condition proved to be, that it would appear that even considerable exposure to weather is better than keeping phthisical patients in close rooms, provided there be no bronchitis or tendency to pneumonia or pleurisy.

Three points, then, are within our control as regards phthisis—arrangement of food, exercise, and pure air.

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* See p. 123, and the Sections on Home and Foreign Service. There are two valuable pieces of evidence of phthisical and scrofulous disease being developed in a healthy population from impure air, viz., Mr Morgan's essay on Phthisis on the West Coast of Scotland (Brit. and For. Med. Chir. Rev.), and the analogous case of Western Canada, given by Mr Mackelcan (Medical Times and Gazette, Aug. 1868).

That food should contain a good deal of the nitrogenous and fatty principles if phthisis is apprehended. Milk has been long celebrated, and lately the koumiss of Tartary has obtained a great reputation in Russia as an agent of cure.[*]

Exercise is of the greatest importance, and it would seem quite clear that this must be in the open air. The best climates for phthisis are perhaps not necessarily the equable ones, but those which permit the greatest number of hours to be passed out of the house.

In the house itself, attention to thorough ventilation, *i.e.*, to constant, though imperceptible movement of the air, is the point to be attended to.

In the case of soldiers, it must also be seen that no weights or straps impede the circulation of blood through the lungs and heart.

The effect of a wet subsoil in the causation of phthisis (see p. 331 for Buchanan's observations) must not be overlooked. Whatever may be the exact amount of truth, we are bound to act as if it were certain.

That the syphilitic disease of the lungs has sometimes a completely phthisical character is tolerably clear, but syphilis will not account for the amount of phthisis in the army. The influence of masturbation in producing phthisis is uncertain.

### *Scurvy.*

The peculiar state of malnutrition we call scurvy is now known not to be the consequence of general starvation, though it is doubtless greatly aided by this. Men have been fed with an amount of nitrogenous and fatty food sufficient not only to keep them in condition, but to cause them to gain weight, and yet have got scurvy. The starches also have been given in quite sufficient amount without preventing it. It seems, indeed, clear that it is to the absence of some of the constituents of the fourth dietetic group, the salts, that we must look for the cause.[†]

Facts seem to show with certainty that in the diet which gives scurvy there is no deficiency of soda or of iron, lime, or magnesia, or of chloride of sodium. Nor is the evidence that salts of potash or phosphoric acid are deficient at all satisfactory. And when we think of the quantity of phosphoric acid which must have been supplied in many diets of meat, and cerealia, which yet did not prevent scurvy, it seems very unlikely that the absence of the phosphates can have anything to do with it.[‡]

The same may be said of sulphur. Considering the quantity of meat and of leguminosæ which some scorbutic patients have taken, it is almost impossible that deficiency in sulphur should have been the cause.

By exclusion, we are led to the opinion that if the cause of scurvy is to be found in deficiency of salts, it must be in the salts whose acids form carbonates in the system. For, if we are right in looking to a deficiency in the fourth class of alimentary principles as the cause of scurvy, and if neither the absence of soda, potash, lime, magnesia, iron, sulphur, or phosphoric acid can be the cause (and it is probable it is not so), then the only mineral ingredients which remain are the combinations of alkalies with those acids which form carbonates in the system, viz., lactic, citric, acetic, tartaric, and malic. That these acids are most important nutritional agents no one can doubt. The salts containing them are at first neutral, afterwards alkaline, from their conversion into carbonates; they thus play a double part, and moreover, when free, and in the presence of albumen and chloride of sodium, these acids have peculiar powers of precipitating albumen, or perhaps of setting free hydrochloric acid. Whatever may be their precise action, their value and necessity cannot be doubted. Without them, in fact, one sees no reason why there should not be a continual excess of acid in the system, as during nutrition a continual excess of acids (phosphoric, sulphuric, uric, hippuric) is produced, sufficient, even when the salts with decomposable acid are supplied, to render all excretions (urinary, cutaneous, intestinal) acid. The only mode of supplying alkali to the acids formed in the body is by the action of the phosphates, which is limited. The only manufacture of alkali in the body is the formation of ammonia, so that these salts are most important as antacids. Yet it is not solely the absence of alkali which produces scurvy, else the disease would be prevented or cured by supply of pure or carbonated alkalies, which is not the case.

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[*] It is now a good deal used in this country.

[†] For a good deal of evidence up to 1848, I beg to refer to a review I contributed on Scurvy to the British and Foreign Medico-Chirurgical Review in that year. The evidence since this period has added, I believe, little to our knowledge, except to show that the preservative and curative powers of fresh meat in large quantities and especially raw meat (Kane's Arctic Expedition), will not only prevent, but will cure scurvy. Kane found the raw meat of the walrus a certain cure. For the most recent evidence and much valuable information, see the Report of the Admiralty Committee on the Scurvy which occurred in the Arctic Expedition of 1875-6 (Blue-Book, 1877).

[‡] Professor Galloway of Dublin, and Mr Anderson of Coventry, have lately written pamphlets urging the claims of potash and phosphoric acid to attention, but without bringing any fresh evidence of sufficient importance to support their views.

When, in pursuing the argument, we then inquire whether there is any proof of the deficiency of these particular acids and salts from the diets which cause scurvy, we find the strongest evidence not only that this is the case, but that their addition to the diet cures scurvy with great certainty.* They will not, of course, cure coincident starvation arising from deficiency of food generally, or the low intercurrent inflammations which occur in scurvy, or the occasionally attendant purpura, but the true scorbutic condition is cured with certainty.

Of the five acids, it would appear unlikely that the lactic should be the most efficacious. If so, how is it that in starch food, during the digestion of which lactic acid is probably formed in large quantities, scurvy should occur? Is, in such a case, an alkali necessary to insure the change of the acid into a carbonate? How is it that scurvy will occur with a milk diet, though, doubtless, milk is a good, though not perfect preservative?

Vinegar is an old remedy for scurvy, and acetic acid is known to be both a preventive of (to some extent) and a cure for scurvy. But it has always been considered much inferior to both citric and tartaric acids. Possibly, as in the case of lactic acid, an alkali should be supplied at the same time, so as to enable the acid to be more rapidly transformed.

Tartaric, and especially citric acids, when combined with alkalies, have always been considered to be the antiscorbutic remedies, *par excellence*, and the evidence on this point seems very complete.†

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* This was most clearly shown in the last Arctic Expedition (1875–6). The rations on board ship during winter were ample, containing dried potatoes and other vegetables, preserved vegetables, pickles, bottled fruits, vinegar, and a daily ration of lime juice, besides raisins and currants. In the sledge expeditions all these were cut off except two ounces of preserved potatoes, an inadequate ration under any circumstances. The meat was pemmican and bacon, and there was, of course, no fresh bread. The result was, that this imperfect diet, conjoined with most laborious work, produced a severe outbreak of scurvy which nearly proved fatal to the whole party. The rapidity with which the sick recovered, on being supplied with lime juice and more favourable diet, was noticeable (see Report, *op. cit.*).

† It is based on a very wide experience, and should not be set aside by the statements of men who have seen only three or four cases of scurvy, often complicated, which happen not to have been benefited by lemon juice. The progress of preventive medicine is checked by assertions drawn from a very limited experience, yet made with great confidence. We must remember that many cases of scurvy are complicated—that the true scorbutic condition, insuffi-

Of malic acid little is known as an antiscorbutic agent, but it is well worthy of extended trials.

Deficiency of fresh vegetables implies deficiency in the salts of these acids, and scurvy ensues with certainty on their disuse. Its occurrence is, however, greatly aided by accessary causes, especially deficiency in food generally, by cold and wet, and mental and moral depression.

The preventive measures of scurvy are, then, the supply of the salts of citric, tartaric, acetic, lactic, and malic acids, and of the acids themselves, and perhaps in the order here given, and by the avoidance, if it can be done, of the other occasional causes.

Experience seems to show that the supply of these acids in the juices of the fresh succulent vegetables and fruits, especially the potato, the cabbage, orange, lime, and grape, is the best form. But fresh fruits, tubers, roots, and leaves are better than seeds. The leguminosæ, and many other vegetables, are useless.

Fresh, and especially raw meat is also useful, and this is conjectured to be from its amount of lactic acid; but this is uncertain.

The dried vegetables are also antiscorbutic, but far less so than the fresh; and the experience of the American War is not so favourable to them as might have been anticipated. Do the citric and other acids in the dried vegetables decompose by heat or by keeping? It would be very desirable to have this question settled by a good chemist. We know that the citric acid in lemon juice gradually decomposes. It does not follow that it should be quite stable in the dried vegetables.

The measures to be adopted in time of war, or in prolonged sojourn on board ship, or at stations where fresh vegetables are scarce, are—

1. The supply of fresh vegetables and fruits by all the means in our power. Even unripe fruits are better than none, and we must risk a little diarrhœa for the sake of their antiscorbutic properties. In time of war *every* vegetable should be used which it is safe to use, and, when made into soups, almost all are tolerably pleasant to eat.

2. The supply of the dried vegetables,* especially potato, cabbage, and cauliflowers; turnips, parsnips, &c., are perhaps less useful; dried peas and beans are useless. As a matter of precaution, these dried vegetables should be issued early in a campaign, but should never supersede the fresh vegetables.

3. Good lemon juice should be issued daily (1 oz.), and it should be seen that the men take it.

4. Vinegar (½ oz. to 1 oz. daily) should be issued with the rations, and used in the cooking.

5. Citrates, tartrates, lactates, and malates of potash, should be issued in bulk, and used as drinks, or added to the food. Potash should be selected as the base, as there is seldom any chance of the supply of soda being lessened. The easiest mode of issuing these salts would be to have packets containing enough for one mess of twelve men, and to instruct the men how important it is to place them in the soups or stews. Possibly they might be mixed with the salt, and issued merely as salt.

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tion, and low inflammation of various organs, lungs, spleen, liver, and muscles, may be all present at the same time. (See also page 325, footnote.) See also paper by Dr Ralfe, of the Seamen's Hospital. (1877. Reprinted from the Lancet.)

* Probably dried fruits, such as raisins and currants (which contain some acid and vegetable salts) are useful as antiscorbutics. The American pemmican contains them, and men are said to live upon it for months together without suffering from scurvy. It appears to have been that kind of pemmican on which the crew of the Polaris lived, who drifted on an iceberg for six months. Other dried fruits, such as apples would probably also be efficacious.

## *Military Ophthalmia.*

The term "military ophthalmia" is often applied particularly to that disease in which the peculiar grey granulations form on the palpebral conjunctiva. But any severe form of purulent ophthalmia spreading in a regiment is often classed under the same heading. Diseases of the eyes are a source of very considerable inefficiency in the army, and even a casual visitor to the Royal Victoria Hospital must be struck by the large number of men he will meet with who have some affection of the eyes. A reference to the Army Medical Reports will also show what great attention is being paid to this important subject by military surgeons, especially by my colleague, Professor Longmore.*

Epidemics of military ophthalmia (grey or vesicular granulations, and rapid purulent ophthalmia), seem to have been uncommon, or perhaps unknown, on the large scale in the wars of the eighteenth century.

The disease, as we now see it, is one of the legacies which Napoleon left to the world. His system of making war with little intermission, rapid movements, abandonment of the good old custom of winter quarters, and intermixture of regiments from several nations, seem to have given a great spread to the disease, and though the subsequent years of peace have greatly lessened it, it has prevailed more or less ever since in the French, Prussian, Austrian, Bavarian, Hanoverian, Italian, Spanish, Belgian, Swedish, and Russian armies, as well as in our own. It has also been evidently propagated among the civil population by the armies, and is one more heritage with which glorious war has cursed the nations.

In some cases, as in the Danish army, it has been absent till manifestly introduced (in 1851); in other instances it has been supposed to originate spontaneously from overcrowding and foul barrack atmosphere, and from defective arrangements for ablution.† Here, as in so many other cases, we find that the question of origin *de novo*, however important, need not be mixed up with that of the necessary preventive measures. What is important for us is to know—*first*, that it is contagious, that is, transmissible; and, *secondly*, that if not produced, its transmissibility is singularly aided by bad barrack accommodation.

NAWAB SALAR JUNG BAHADUR

The measures to be adopted if military ophthalmia prevails—

1. *Good Ventilation and Purity of the Air.*—In the Hanoverian army, Stromeyer reduced the number of cases in an extraordinary degree, simply by good ventilation. The only explanation of this must be that the dried particles of pus and epithelium, instead of accumulating in the room, were carried away, and did not lodge on the eyelids of the healthy men. The evolution of ammonia from decomposing urine has also been assigned as a cause, and this would be also lessened by good ventilation.

It would appear likely that bad barrack air predisposes to granular conjunctivitis by producing some peculiar state of the palpebral conjunctiva and glands (Stromeyer and Frank), and if a diseased person then introduces the specific disease, it spreads with great rapidity, or possibly, as Mr Welch's facts seem to show, the impure atmosphere is the great cause, and contagion only secondary.

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* Ophthalmoscopes are now issued to the different stations, and an Ophthalmoscopic Manual has been drawn up by Mr Longmore for the use of army medical officers. As giving a good survey of military ophthalmia in the British army, the excellent papers of Dr Frank (Army Medical Report for 1860) and Dr Marston (*Beale's Archives*) should be also referred to. A very interesting paper has also been published by Mr Welch, 22d regiment (Army Medical Report, vol. v. p. 494, 1865), on the Causes aiding the Development of Granulations at Malta. A warm, moist, impure atmosphere is shown to have a great influence.

† See Dr Frank's papers (Army Medical Report for 1860, p. 406) *for some remarks on its spontaneous origin.*

2. *Careful Ablution Arrangements.*—An insufficient supply of water for cleansing basins, and the use of the same towels, are great means of spreading the disease, if it has been introduced. Whenever men use the same basins, they should be taught to thoroughly cleanse them; and it would be well if, in every military ablution room, the men were taught not only to allow the dirty water to run away, but to refill the basin with water, which the next comer would let off before filling with fresh water for himself. If some mechanism could be devised for this, it would be very useful. The same towel is a most common cause of propagation; or a diseased man using always the same towel may reinoculate himself. The towels should be very frequently washed (probably every day), and should be dried in the open air, never in the ablution room or barrack.

In some cases special ablution arrangements may cause a good deal of granular conjunctivitis. In 1842 and 1843 I witnessed, in a regiment newly landed in India from England, a very great number of cases of this kind; the supply of water was very insufficient, many men used the same basins, which were very imperfectly cleaned; the same basins were used for washing, and also for dyeing clothes; at that time the men in the cold months wore trousers of a black drill, and when the dye came off they were accustomed to rudely replace it; they themselves ascribed the very prevalent ophthalmia to the irritating effect of the particles of the dye left in the basins, and getting into the eyes. There were enormous granulations on both upper and lower lids, and the disease was believed to be communicable, but whether the affection was strictly to be classed with the vesicular granulations I do not know.

3. In some cases the use of the bedding (pillows and pillow cases), which has been used by men with grey granulations, has given the disease to others, and this has especially occurred on board transports. In time of war especially this should be looked to. If any cases of ophthalmia have occurred on board ship, all the pillows and mattresses should be washed, fumigated, and thoroughly aired and beaten. The transference has been in this case direct, particles of pus, &c., adhering to the pillow and mattresses, and then getting into the eyes of the next comers.

4. Immediately the disease presents itself, the men should be completely isolated, and allowed to have no communication with their comrades. It has been a great question whether a Government is justified in sending soldiers home to their friends, as the disease has been thus carried into previously healthy villages. It would seem clear that the State should bear its own burdens, and provide means of isolation and perfect cure, and not throw the risk on the friends and neighbours of the soldier.

An important matter to remember in connection with grey granulations is, that relapses are very frequent; a man once affected has no safety (Warlomont); simple causes of catarrh and inflammation may then reinduce the specific grey granulations with their contagious characters; so that a man who has once had the disease is a source of danger, and should be watched.

### *Venereal Diseases in the Army.*

It is convenient for our purpose to put together all diseases arising from impure sexual intercourse, whether it be a simple excoriation which has been inoculated with the natural vaginal mucus or with leucorrhoeal discharges, and which may produce some inguinal swelling, and may either get well in a few days or last for several days; or whether it be an inflammation of the urethra produced by specific (or non-specific? leucorrhœal?) discharge; or whether it be one of the forms of syphilis now diagnosed as being in all probability separate and special diseases, having particular courses and terminations.

In the army men enter the hospital from all these causes, and from the remoter effects of gonorrhœa or syphilis, orchitis, gleet, stricture, bladder and kidney affection; or syphilitic diseases of the skin, bones, eyes, and internal organs.

The gross amount of inefficiency in the army is tolerably well known, but it will require a few more years before the several items of the gross amount are properly made out. This arises partly from an occasional great difficulty in the diagnosis of true infecting syphilis, and partly from a want of uniformity in nomenclature.

The comparative amount of army and civil venereal diseases is not known, because we have no statistics of the civil amount. It is no doubt great. It is a question whether a large majority of the young men of the upper and middle classes do not suffer in youth from some form of venereal diseases. In the lower classes it is perhaps equally common.

The sequences are most serious; neglected gleet, stricture, secondary and tertiary syphilis, are sad prices to pay for an unlawful (in some cases a momentary) gratification; and in the army the State yearly suffers a large pecuniary loss from inefficiency and early invaliding. In campaigns the inefficiency from this cause has sometimes been great enough to alarm the generals in command, and to increase considerably the labour and sufferings of the men who are not affected.

The preventive measures against venereal diseases are—

1. *Continence.*—The sexual passion in most men is very strong. Providence has, indeed, made it strong enough to lead men to defy all dangers, and to risk all consequences. It has been supposed by some that, in early manhood, continence is impossible, or if practised, is so at the risk of other habits being formed, which are more hurtful than sexual intercourse, with all its dangers. But this is surely an exaggeration; the development of this passion can be accelerated or delayed, excited or lowered, by various measures, and continence becomes not only possible, but easy.

For delaying the advent of sexual puberty and desire, two plans, in addition to the restraints of religious duty, can be suggested—absence from exciting thoughts and temptation, and the systematic employment of muscular and mental exercise. The minds of the young are often but too soon awakened to such matters, and obscene companions or books have lighted up in many a youthful breast that *feu-d'enfer* which is more dangerous to many a man than the sharpest fire of the battlefield would be. Among young soldiers this is especially the case; while, in spite of the exciting literature of the day, and of the looseness of some of the older boys at the public schools, or at the universities, the moral tone of the young gentlemen of our day is better than it was some half century ago, the conversation of the classes from which the soldier is drawn is still coarse and lewd as in the middle ages. There is too close a mixture of the sexes in the English cottages for much decency, and the young recruit does not often require the tone of the barrack to destroy his modesty. In fact, it is possible that, in good regiments, he will find a higher moral tone than in the factory or the harvest field.

We must trust to a higher cultivation, and especially to religious influences, to introduce among the male youth of this nation, in all its grades, a purer moral tone, so that the safeguard of modesty and religious scruples may be cultivated, and not destroyed. In the army, the example of the officers, and their exertions in this way, would do great things, if we could hope that the high moral tone which happily exists in some cases could inspire all.

If exciting and lewd conversation and thoughts should be discouraged by moral and religious teaching, it is not the less necessary to save the young from temptation. The youth of this nation are now sorely tempted, for in our streets prostitution is at every corner. Whatever may be the objection to police regulations, we have surely a right to demand that the present system of temptation shall be altered. It may not be easy to exclude all prostitutes, especially of the better class (whose calling is less easily brought home to them), from public thoroughfares, but, practically, open prostitution can be recognised and made to disappear from our streets. It has been said our police regulations are sufficient for this; they have never yet proved so; and in no European country but England is prostitution so open and so undisguised.*

In the Acts passed in 1864,† 1866, and 1869, and in the Licensing Act of 1872 (Acts of the greatest importance, as the first steps in an efficient legislation), authority has been now taken to prevent prostitutes from assembling in the publichouses, and to a certain extent sources of temptation have been removed.

If young men can thus escape an appeal to their passions, continence is much more easy. There are times when the strictest virtue may well dread such an appeal. Human nature is but too weak, and needs every safeguard it can get.

As aids to continence, great physical and mental exertion are most powerful. It would seem that, during great exercise, the nervous energy is expended in that way, and erotic thoughts and propensities are less prominent; so also with mental exercise, in perhaps a less degree. The establishment of athletic sports, gymnasia, and comfortable reading-rooms in the army, may be expected to have some influence.

Temperance is a great aid to continence. In the army, the intemperate men give the greatest number of cases of syphilis; and when a man gets an attack, it is not infrequently found that he was drunk at the time.

The measures which promote continence are then—

(*a*) The cultivation of a religious feeling, and of pure thought and conversation among the young soldiers, by every means in our power.

(*b*) Removing temptation and occasions to sin.

(*c*) Constant and agreeable employment, bodily and mentally; as idleness is one great cause of debauchery.

(*d*) Temperance.

2. *Marriage.*—It is very doubtful whether those who condemn early marriages among the working classes, on account of improvidence, are entirely right in their argument. The moral effect of prolonged celibacy has seldom been considered by them. Probably the early marriages are the salvation of the working youth of this country; and in the present condition of the labour market, the best thing a working-man can do is, as early a possible, to make his home, and to secure himself both from the temptations and expenses of bachelorhood. In the case of the soldier the conditions are different for different men; the private soldier who has enlisted for long service (12 years,

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* The effect of this upon the virtuous female population is very serious. Every servant in London sees the fine clothes and hears of the idle luxurious lives of the women of the town, and knows that occasionally respectable marriage ends a life of vice. What a temptation to abandon the hard work and the drudgery of service for such a career, of which she sees only the bright side! It is a temptation from which the State should save her. She should see prostitution as a degraded calling only, with its restrictions and its inconveniences.

† An Act for the Prevention of Contagious Diseases at Certain Naval and Military Stations, 1864; an Act for the better Prevention, &c., 1866 (cited as Contagious Diseases Act, 1866).

and prospect of renewal) cannot marry for seven years, and then only 7 per cent. can marry with leave. It was difficult to avoid this, and the consequences were certainly most serious. Under the new system of six years' enlistment, and passage into the reserve, a soldier will not marry at all, and it is of course desirable he should not do so. If he enlists at eighteen, at twenty-four he will be free; and if kept in full occupation, and as far as possible shielded from temptation, the burden of celibacy will not weigh upon him. Continence would be desirable for his health, and for the welfare of his future offspring. The short service now introduced may indeed greatly influence this matter, and certainly has removed from pressing discussion the question of marriage in the infantry of the army.

3. *Precautions against the Disease.*—Admitting that, in the case of a body of unmarried men, a certain amount of prostitution will go on,* something may be done to prevent disease by extreme cleanliness, instant ablution, and by the use of zinc, alum, and iron washes, or similar lotions after connection, and by the constant use by prostitutes of similar washes. It may seem an offence against morality to speak of such things; but we must deal with things as they are; and our object now is not to enforce morality, but to prevent disease. The use in brothels of these measures appears to be more efficacious than any other plan. In some of the French towns the use of lotions and washings is rigorously enforced, with the effect of lessening disease considerably.

4. *Detection and Cure of Diseased Men and Women.*—In the case of the soldier who has medical advice at hand, it seems of the greatest importance to have instant medical aid at the first sign of disease. But, instead of this, the soldier conceals his ailment as long as possible, because he will be sent to hospital, put under stoppages, &c. A late regulation has made this even more stringent, but surely its wisdom may be questioned. Surely the soldier should be encouraged to make immediate application, and he should certainly not be punished for a fault which his superiors commit with impunity, and for which the State is in part answerable by enforcing celibacy. Our object is to preserve the man's health and services for the State; we shall not accomplish this by ignoring what is a common consequence of his conditions of service. Health inspections, which are not now obligatory, ought, in my opinion, to be made weekly by the surgeon. I believe these inspections, when carefully made, to be of the greatest service. Some medical officers used to consider them derogatory to themselves, and slurred them over. I can

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* While saying this, and while dealing with what actually exists, I do not, for a moment, share the opinions of those who look on prostitution not only as a necessity, but as a good—as a shield against worse vices, and as a guard against attempts on married virtue. One feels instinctively that such arguments, however plausible at first sight, are untrue. In fact, they do not bear investigation. Develop the case to a general rule (as Paley advised to be done in all arguments), and its fallacy is manifest. The more prostitution is extended, the more encroachment does it make on marriage—the safeguard of the human race. In its smallest degree it does this. If extended, prostitution would begin to shake the very structure of society, for the relation of the sexes, the improvement of both men and women, and the care and culture of the offspring, would become endangered. The more it is considered, the more clearly will the terrible consequences of an extended prostitution come out. But apart from this general view, the effect on the individual man is disastrous, even if he escape venereal disease. Association with a single woman is a safeguard against excess; but if the appetite is stimulated by constant variety, it is impossible to avoid excess, and its enfeebling effects on the body. It is worse than polygamy, as sexual intercourse with different females is more varied. In polygamy, also, it is well known that our common notion of a great number of wives is erroneous; a stop is put by the expense; and in the polygamous nations the majority of men have only one wife. Whenever station or riches enable a man to have more, he pays for his gratification by an enfeebled health, and by a degenerate offspring.

It is not without physiological cause that Christianity has forbidden prostitution, in terms which make us understand, even better than the writings of Terence or Juvenal, how widespread and deadly was the prostitution of antiquity, and how the strength and wellbeing of men were being undermined. Is there no danger that we may require similar warnings?

neither participate in, nor indeed understand, a feeling of this kind; it seems to me a matter of duty, which should be done as conscientiously as possible. I know from personal experience of health inspections in the army how many men are caught in an early stage of syphilis and gonorrhœa, and the disease is forthwith cured, or greatly mitigated. Some suppose they are derogatory to the men; but they were practised for many years, and no such feeling was excited.

It has been also proposed to detect and cure the disease in prostitutes. A great outcry has been raised against this proposal, which is yet a matter of precaution which the State is surely bound to take. A woman chooses to follow a dangerous trade—as dangerous as if she stood at the corner of a street exploding gunpowder. By practising this trade she ought at once to bring herself under the law, and the State must take what precautions it can to prevent her doing mischief. The State cannot prevent prostitution. We shall see no return to the stern old Scandinavian law which punished the prostitute with stripes and death; but it is no more interference with the liberty of the subject to prevent a woman from propagating syphilis, than it would be to prevent her propagating smallpox.

The difficulty is to detect when she is diseased. Abroad, an elaborate system is in use for this purpose; brothels are registered, and their inmates regularly examined. In this country such a system seems to many people too like a recognition of the inevitableness of prostitution, and to a certain extent a sanction of it. It does not present itself to me in this light, but as a simple matter of precaution. A custom exists which we cannot set aside; let us obviate its effects as best we may, while, at the same time, by higher culture and better religious teaching, we endeavour to gradually remove the custom.*

A partial adoption of this plan has been commenced by the military and naval authorities in this country, and Acts have been passed (1864, 1866, and 1869) by means of which the prostitutes of certain military and naval stations are brought under supervision.† The important clause in the Act for 1866 is clause 15, which provides that when an information is made on oath that a woman is a common prostitute, living within the limits of any place to which the Act applies, or having been within those limits for the purpose of prostitution, a justice may issue notice to such woman, through the superintendent of police, to appear for medical examination. She is then kept under continued inspection, and certified Lock Hospitals are provided for her treatment if she is discovered to be ill. Clause 36 is also an important one; it imposes a penalty of £20, or imprisonment, with or without hard labour, on any brothel-keeper or owner of a house who, having reasonable cause to know a woman to be a prostitute, and to be affected with a contagious disease, allows her to resort to the house for the purpose of prostitution.

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* Those persons who shut their eyes to the enormous prostitution of this country, as of all others, or think nothing can be done because it is impossible to deal with private or "sly" prostitution, and with the higher grades of the calling, should remember that some movement in the interest of the unhappy girls themselves is necessary. In the low brothels in London the system is a most cruel one. A girl is at first well treated, and encouraged to fall into debt to her employer. As soon as she is fairly involved, she is a slave; there is no relief till she can make no more money, when she is cast out. Surely something should be done to save her. Possibly it might be well to try the plan of recognising no debts from a girl to the procuress or brothel-keeper, and to also devise means for at once giving her the means of release from her life if she desires it. Also, if such houses must exist—and who can venture to hope they will not!—they may at least be made less indecent, quieter, and safer from theft, and even murder. At present, the system, as it exists, is a gigantic scandal to Christianity, and Jeannel's singular work has lately shown how curious a parallel there is between modern prostitution and that which dimmed the splendour, and perhaps hastened the fall, of Imperial and Pagan Rome. Eighteen centuries after the death of Christ, are we still at such a point!

† The military stations named in the Contagious Diseases Act in 1866, are Portsmouth, Plymouth, and Devonport; Woolwich, Chatham, and Sheerness; Aldershot, Windsor, Colchester, Shorncliffe, Curragh, Cork, and Queenstown. Others have since been added. Adjoining parishes are in many cases included.

This Act came into force on the 1st October 1866; and in some stations, as at Aldershot, it was really more than half a year after this time before it could be put into force.

*Admissions of Primary Venereal Sore per 1000 of Strength.*

| | 1867. | 1868. | 1869. | 1870. | 1871. | 1872. | 1873. | 1874.* | 1875.* | 1876.* |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stations under the Act.** | | | | | | | | | | |
| Plymouth, . | 76 | 66 | 74 | 58 | 50 | 59 | 37 | 36 | 29 | 27 |
| Portsmouth, . | 116 | 86 | 62 | 51 | 41 | 40 | 44 | 48 | 30 | 27 |
| Chatham, . | 71 | 68 | 41 | 47 | 65 | 49 | 41 | 33 | 17 | 33 |
| Woolwich, . | 88 | 46 | 52 | 48 | 58 | 60 | 60 | 47 | 59 | 42 |
| Aldershot, . | 81 | 77 | 63 | 67 | 65 | 62 | 72 | 52 | 46 | 47 |
| Dover, . . | 132 | 111 | 80 | 30 | 24 | 47 | 38 | 37 | 27 | 30 |
| **Stations not under the Act.** | | | | | | | | | | |
| London, . . | 163 | 148 | 144 | 160 | 190 | 199 | 185 | 179 | 187 | 146 |
| Sheffield, . . | 163 | 107 | 146 | 77 | 126 | 98 | 71 | 49 | 87 | 119 |
| Manchester, . | 177 | 115 | 160 | 92 | 70 | 98 | 91 | 106 | 89 | 113 |
| Dublin, . . | 129 | 139 | 180 | 128 | 117 | 165 | 136 | 95 | 73 | 76 |
| Isle of Wight, | 59 | 103 | 129 | 64 | 66 | 57 | 37 | 89 | 89 | 54 |
| Belfast, . . | 89 | 56 | 52 | 43 | 61 | 78 | 103 | 64 | 44 | 57 |

Since the passing of these Acts there has been a most decided decrease in the number of primary venereal sores at all the military stations under the Acts, compared with non-protected stations. And this is the more satisfactory, because the frequent movement of the troops, and the number of stations where there is no contrôl of disease, render the working of the Acts difficult. The record for the years 1867–76 at a few stations will show the decrease (see above).

Of course, it is difficult to compare garrison and commercial towns, still the above figures show a decided decline in the controlled stations.

But the following figures, kindly given me by Dr Balfour, are quite convincing.

In 1871 and 1872 there were fourteen stations under the Contagious Diseases Act, with a mean strength of 51,400 men; putting against these other fourteen stations not under the Act, with an average strength of 19,953 men, we have the following ratio :—

*Admission per 1000 of Strength.*

| | | Primary Venereal Sore. | Gonorrhœa. |
|---|---|---|---|
| Stations under the Act, . | 1871, | 50·6 | 116·9 |
| | 1872, | 53·3 | 105·1 |
| Stations not under the Act, | 1871, | 93·4 | 107·4 |
| | 1872, | 123·2 | 105·9 |

It must be remembered that at present gonorrhœa has not been touched by the Act, for want of hospital accommodation, so that the equal amount of gonorrhœa of the two classes shows that the enormous lessening of primary venereal sore in the controlled stations is owing to a real diminution of syphilis, and not to lessened frequency of intercourse.* This is proved again by the following figures given me by Dr Balfour.

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* Stoppage of pay in force.

In 1864, the year before the Act came into operation, the average admissions at all the stations from primary venereal sore were 108·6 per 1000. In 1872, at the uncontrolled stations, the number was still higher, being 123·2, so that syphilis had not declined in the uncontrolled stations. But, as already said, in the controlled stations in 1872, the admissions were only 53·3. Therefore, the gain to the State in the controlled stations was (108·6–53·3) 55 admissions less per 1000 of strength; and in a mean strength of 50,000 men the State was saved the cost of 2750 cases of primary venereal sore in that year, and the men were saved the enormous injury to their health, which would otherwise have resulted.

Let the facts be put in another form. Taking the first seven years that the Acts were in operation (before the introduction of the stoppage regulation in 1873), viz., 1865–72 (though in the early years the operation was partial and imperfect), we have the following figures :—

*Admission per* 1000 *of Strength*, 1865–72 *inclusive.*

| | Primary Sores. | Gonorrhœa. |
|---|---|---|
| All stations not under the Act (mean strength 32,528 men), . . . . | 103·1 | 111·9 |
| Stations under the Act (mean strength 30,765 men), . . . . . . . . . | 62·8 | 115·0 |

There was therefore a practical identity in gonorrhœal admissions, but the annual admissions for primary venereal sores were reduced in the controlled stations by 40·3 per 1000. In the eight years the State was therefore saved very nearly 10,000 cases of syphilis; and supposing each demanded twenty days of treatment (which is moderate), 200,000 days of sickness have been saved in eight years.

Such, then, has been the operation of the Act under many disadvantages, but this has not been its only beneficial effect.

The Act at the large stations has done great good in some other directions, especially as regards the women. Many women have been reclaimed; the horrible juvenile prostitution has almost ceased, and comparative decency has been taught in the hospitals. Still the Act is too feebly drawn, and too partially carried out, to cope entirely with the evil. The prostitutes are not thoroughly under inspection; many are not inspected at all; neighbouring towns send in prostitutes; and hospital accommodation is insufficient.

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* In the return for 1876, we find the following :—

| | Primary Venereal Sore. | Gonorrhœa. |
|---|---|---|
| 14 Stations under the Act, strength 48,620, . . | 33 | 66 |
| 14 Stations not under the Act, strength 18,790, . | 86 | 89 |

*All* the stations not under the Act, grouped together, show a mean strength of 38,073, with 2,416 admissions for primary venereal sores, or 63 per 1000, against 33 per 1000 in the stations under the Act. The difference is thus maintained in the stations under the Act. Much has been made by the opponents of the Acts, of the fact that the men (since 1873) have been subjected to stoppages, which has (presumably) led to concealment of disease. But it is obvious that if this be the case, the influence must affect *all* stations equally, yet we still find the highest ratios (even in gonorrhœa) in the non-protected stations.

The prostitutes from surrounding districts not in the Act also come into these towns and camps, either remaining for a few days and then disappearing, or, if diseased, stopping till they can get admitted into hospital. Regiments coming from other quarters not under the Act; men coming from furlough or detachment, also introduce the disease; in fact, the means of evasion and of re-introduction are numerous.

One consequence of the Contagious Diseases Act was to make public the most frightful state of things among the women of our garrison towns. The vivid picture of the Chatham prostitute's life, drawn by Mr Berkeley Hill,* was no exaggeration. Reports from the Lock hospitals at other places would, if published, have borne out all Mr Hill alleged. Shocking as these disclosures are, and mortifying as they may be to our national pride, it is by far the best plan to have them made. An evil like this must not be treated in the shade; it will never be overcome till the public know its proportions; the deadly mists which cling round and poison the very basis of society can be dispersed only when the healing light of the sun falls on them. It is at any rate encouraging to learn that the effect of the Act has been greatly to improve the manners and habits of the women—to impose some restraint on them, and to restore to them something that, in comparison with their former life, may be called decency.

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* British Medical Journal, 1867.

# CHAPTER XIX.

# DISINFECTION.

The term "disinfectant," which has now come into popular use, has unfortunately been employed in several senses. By some it is applied to every agent which can remove impurity from the air;[*] by others, to any substance which, besides acting as an air purifier, can also modify chemical action, or restrain putrefaction in any substance, the effluvia from which may contaminate the air; while, by a third party, it is used only to designate the substances which can prevent infectious diseases from spreading, by destroying their specific poisons. This last sense is, I conceive, the most correct, and it is that which is solely used here. The mode in which the poisons are destroyed, whether it be by oxidation, deoxidation, or arrest of growth, is a matter of indifference, provided the destruction of the poison is accomplished. The general term, "air purifier," is given in this work to those agents which in any way cleanse the air, and which therefore include disinfectants (see page 135 for the Air Purifiers), and the term, "Sewage Deodorants," to those substances which are used to prevent putrefaction in excreta, or in waste animal or vegetable matters, or to remove the products of putrefaction (see page 398 for the Sewage Deodorants).

The chief human diseases which are supposed to spread by means of special agencies (conveniently designated under the name of "contagia"),[†] are the exanthemata; typhus exanthematicus; enteric (typhoid) fever; relapsing fever; yellow fever; paroxysmal and the allied remittent fevers; dengue; cholera; bubo-plague; influenza; hooping-cough; diphtheria; erysipelas; dysentery (in some cases); puerperal fever; syphilis; gonorrhœa; glanders; farcy; and malignant pustule. There are some few others more uncommon than the above.

The term "disinfectant" might also be applied to substances destroying entozoa, or epiphytes or entophytes, but there is a disadvantage in giving it so extended a meaning.

It has long been a belief that the spread of the infectious diseases might be prevented by destroying the agencies in some way, and various fumigations, fires, and similar plans have been employed for centuries during great epidemics.

In order to apply "disinfection," in the modern sense of the term, we ought to know—1*st*, the nature of these contagious agencies; 2*d*, the media through which they spread; and 3*d*, the effect produced upon them by the chemical methods which are supposed to destroy or modify them.

### 1. *The Nature of the Contagia.*[‡]

This point is at present the object of eager inquiry. In the case of one or two of the above diseases, the question has been narrowed to a small compass. In variolous and vaccine discharge, and in glanders, the poison certainly exists in the form of solid particles, which can be seen by high powers as glistening points of extreme minuteness.* In cattle plague blood serum there are also excessively small particles discovered by Beale, which are probably the poison. The size of the particles supposed to be contagia is most minute; some of them are not more than $\frac{1}{50000}$ of an inch, and Beale believes that there may be smaller still to be discovered with higher powers. Chauveau has washed the vaccine solid particles in water; the water did not become capable of giving the disease; the washed particles retained their power. The epidermic scales of scarlet fever and the pellicle of the diphtheric membrane certainly contain the respective poisons, and after exposure to the air for weeks, and consequent drying, still retain their potency. It is more likely that solid matters should thus remain unchanged than liquids, but it has not yet been proved that this is so, and at present the exact physical condition of the contagia of the other infectious diseases remains doubtful.

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[*] Tardieu, for example, Dict. d'Hyg. art. Disinfection, and many other authors.

[†] It will be seen that the old distinctions between infectious and contagious diseases, and between miasmata and contagia, are not adhered to. They were at no time thoroughly definite, and are now, I think, better abandoned.

[‡] For a fuller description on some of these topics than can be given here, I beg to refer to my Report on Hygiene for 1872 (Army Medical Department Blue Book, vol. xiii.).

The extraordinary power of increase, and capability of producing their like, possessed by some of the contagia when placed under special fostering circumstances, as in the bodies of susceptible animals, lead to the belief that they are endowed with an independent life. The old doctrines that they are simply either poisonous gases or animal substances in a state of chemical change, and capable of communicating this change, or that like the so-called ferments (ptyalin, pancreatin, diastase, emulsin), they split up certain bodies they meet, are not now in favour.

The retention of the power of contagion for some time, and its final loss, the destruction of the power by antiseptics which do not affect the action of such bodies as ptyalin or diastase, and the peculiar incubative period which is most easily explained by supposing a gradual development of the active agent in the body, are more in accordance with the hypothesis of independent life and power of growth.

The independent living nature of the contagia is a belief which has long been held in various forms. At the present time there are three views, each of which has some arguments in its favour.

(1.) The particles are supposed to be of animal origin, born in, and only growing in the body; they are, in fact, minute portions of bioplasm (to use Dr Beale's phrase), or protoplasm.†

This is the old doctrine of "fomites" expressed in a scientific form, and supported by a fact which was not known until lately. This is that the independent life ascribed to these particles of bioplasm is no assumption, since we are now aware that many of the small animal cells or bioplastic molecules are virtually independent organisms, having movements, and apparently searching for food, growing, and dying.

This view explains singularly well the fact of the frequent want of power of the contagia of one animal to affect another family; as, for example, the non-transference of many human diseases to brutes, and the reverse. It also partly explains the non-recurrence of the disease in the same animal by supposing an exhaustion of a special limited supply of food, which cannot be restored, since it may be supposed that some particular bodily structure is altogether destroyed, as, for example, Peyer's patches may be in enteric fever. One objection to this view is, on the other hand, that living animal particles die with great rapidity after exit from the body, while the contagia do certainly last for some considerable time.[*]

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* The observations of Chauveau, Beale, and Burdon-Sanderson, and still more recently, of Braidwood and Vacher, prove this very important point by what seems indisputable evidence. It does not follow that all small bodies are in such fluids the "contagia," but the experiments prove that some of them must be. In many kinds of blood there are numerous small particles, derived, according to Riess, from retrograde metamorphosis of white blood cells, and which have no contagious property.

† This view has been advocated with great force by Beale (Disease Germs, 2d edition); and Morris (The Germ Theory of Disease, 2d edition).

(2.) The particles have been conjectured to be of fungoid nature, and to simply grow in the body after being introduced *ab externo.* This view is supported by the peculiarities of the rapid and enormous growth of fungi, by their penetrative powers and splitting up action on both starchy, fatty, and albuminoid substances, and by the way in which certain diseases of men and of animals[†] are undoubtedly caused by them. It is clearly a view which would explain many phenomena of the contagious diseases, and has been supported by the experimental evidence of Hallier and many others who have believed either that they have invariably identified special fungi in some of these diseases, or that they have succeeded in cultivating fungi from particles of contagia. At the present time, however, the evidence of true and recognisable and special fungi being thus discovered and grown, and forming the efficient causes, is very much doubted by the best observers. The micrococci of Hallier, supposed to be formed by the disintegration of the protoplasm of fungi, and which Hallier considers can again develop to fungi, are looked upon by many as mere detritus.[‡]

(3.) The particles of contagia are thought to be of the nature of the "Schizomycetes," *i.e.*, of that class of organisms which Nägeli has separated from the fungi, and which form the lowest stratum at present known to us of the animate world. They are termed Bacteria, Zooglœa, Microzymes, Vibrios, Monads, &c. Their relation to the fungi, or to the Oscillarineæ, to which they are perhaps closer, is yet a matter of warm debate.

That these creatures are concerned in many diseases is clear.[§] Lister's genius first brought their practical importance forward, and the late researches of Klebs, Recklinghausen, and others, have shown how great a part they play in the production of Septicæmia. The carbuncular disease of cattle and sheep (splenic apoplexy) is also intimately connected with Bacteria ; and if the observations of Coze and Feltz are correct, the same is true of typhoid fever. Ferdinand Cohn has lately asserted[‖] that even the glistening particles of vaccine lymph are Bacteria. Bacteria have been proved to cause disease of the intestinal mucous membrane, the uterus, the kidneys, and the heart, and they play some part in hæmorrhagic smallpox.

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[*] A modification of this view under the name of the Glandular Origin of Disease, is advocated by Dr B. W. Richardson, F.R.S. (Address to the Sanitary Institute of Great Britain, Leamington, 1877, *Nature*, No. 414, Oct. 4. 1877, p. 480). Admitting that the disease poison generally comes from without, he looks upon its action as catalytic, causing an altered glandular secretion or a change in the blood, the changed secretion reacting on the nervous centre supplying the gland or glands. He also conceives that during epidemic periods a strong nervous impression may have the same effect as the direct introduction of poison from without, so that the disease may occasionally arise spontaneously. He looks upon many diseases as hereditary, in the sense that the condition of the child resembles that of the parent, and will therefore be open to similar influences.

[†] Not only some skin and hair diseases of men and animals, and diseases of insects and fishes are caused by the growth of fungi which fall on the surface of the body, or are drawn into the mouth, but internal diseases are caused by the growth of undoubted fungi, as Aspergillus.

[‡] The supposed fungus, which Klein (Reports of the Medical Officer of the Privy Council, new series, No. vi. 1875) thought he had discovered in the patches of typhoid ulceration, was shown by Creighton to be merely an altered condition of fibrine simulating an independent organism (see Proceedings of the Royal Society, June 15, 1876).

[§] For a short summary of this subject, see my Report on Hygiene for 1872, in the Army

[‖] Virchow's Archiv. band lv. p. 229 (1872).

Yet it is certain that in some of the epidemic diseases there are no Bacteria. In cholera, Lewis and Cunningham have failed, in spite of the most persevering search, to find Bacteria (or fungi) in the discharges or blood of cholera.

The reasons for attributing in many cases great influence to the Bacteria, which are undoubtedly present, are obvious enough.

They are so widely spread in nature (in air, it is believed, and in water); their powers of growth, by division, are so wonderful; their food (ammonia, phosphates, and perhaps starches or sugars) is so plentiful, and their tenacity of life so great, that it is no wonder great consequence is now attached to them. Yet it is their very universality which is the strongest argument against the view that they constitute the contagia of any of the specific diseases, and any one who considers the peculiar spread of the contagious diseases will admit the force of this objection. To meet this objection, it has been surmised that they are not the contagia, but merely their carriers. This view has not been defined; but as the plasma of Bacteria is albuminoid, it may perhaps be taken to mean that while the Bacteria are usually harmless, their plasma may become, in certain cases, altered in composition, and then becomes poisonous in different specific ways. Bacteria feeding in the blood of a typhus patient will become nourished with morbid plasma, and thus, so to speak, it is diseased Bacteria which become dangerous. We get here beyond the range of present observation, and are conscious how impossible it is with our present instruments to investigate such an hypothesis.*

The belief which some entertain that the Schizomycetes are the efficient agents of the contagious diseases has led to a number of experiments on the destruction of Bacteria by heat and by chemical agents, in the belief that the doctrine of disinfection was thereby elucidated. This could hardly be the case, unless we are certain that the Bacteridia are the contagia, which is not the case in some of those diseases, and not proved to be so in any. Disinfection must rest at present on its own experimental evidence.

The belief in the part played by Bacteridia has led also to much interest being taken in the discussion on ferments, and in the question of spontaneous generation, as it is imagined that a clue might thus be found to the origin, *de novo*, of the contagia. Mr Darwin's doctrine of Pangenesis has even been pressed into the discussion, though it rather makes the darkness greater than before. It is curious to find so practical a matter as that of disinfection brought into relation with some of the most subtle and controverted questions of the day; but the important bearing which the acceptance of one or other of these views would have on the practice of disinfection is evident.

If the "contagia" are simply excessively minute portions of bioplastic particles, in Beale's sense, we may be sure they will be easily killed; a heat far below that of boiling water, and very weak chemical agents, destroy all signs of vitality in animal cells and molecules. We might, therefore, hope much from disinfection. Fungi in water are destroyed by a comparatively low heat; while in dry air *Penicillium glaucum* is not completely destroyed, according to Pasteur, till 127° C. (= 270° Fahr.), and *Oidium aurantiacum* dies at about the same temperature. On the contrary, the Bacteroid bodies are often extremely stable. Lex found a temperature of 127° C. or 262°·6 Fahr. insufficient to kill them, and after boiling them for half an hour they still showed vital movements; and in Calvert's experiments a heat of no less than 400° Fahr. (= 204° C.) was required to thoroughly destroy them, and some kinds seem unaffected even by strong acids and caustic alkalies.* Sanderson found that Bacteria in water are not developed in fluids heated to 366° Fahr. or even boiled. Disinfection, if Bacteridia are to be destroyed, would be then a matter of much greater difficulty. Important in all ways, this question of the nature of contagia is especially so in a practical sense, viz., that of the easy or difficult destruction of these agents.

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* For further information see the Address in Medicine by W. Roberts, M.D., F.R.S., delivered at the Manchester meeting of the British Medical Association, 1877, (Brit. Med. Journal, No. 867, Aug. 11, 1877, p. 168). Also Professor Tyndall's papers in the Royal Society's Proceedings and Transactions (see Transactions of the Royal Society, 1876, part i. p. 27).

### 2. *The Media in which the Contagia are spread.*

Our knowledge of this point is far more defined, and may be thus summarised:—

The special and distinctive phenomena of each disease are usually attended with special implication of some part of the body, and it is especially these parts which contain the contagia. In these parts there is frequently rapid growth, and if the parts are on the surface, frequent detachment. The pus and epidermis of smallpox; the epidermis and the mouth and throat epithelium of scarlet fever; the skin and bronchial secretions of measles; the stools containing the discharged detritus of Peyer's glands in typhoid fever; the discharges of cholera; the discharges and eruptions of syphilis, glanders, farcy, and malignant pustule, are instances of this. In typhus fever the skin is greatly affected, and it is generally supposed that it is from the skin that the virus spreads, since this disorder is so easily carried by clothes; the same is the case with plague. In fact, those parts of the body which are the breeding-places of the contagious particles give off the poison in greatest amount. The portions of the body thus thrown off, and containing the contagia, may then pass into air, or find their way into water or food, and in this way be introduced by breathing, drinking, or eating, or through broken surfaces of the body.

The principles of disinfection ought evidently then to deal with the poisons, at their seats of origin, as far as these are accessible to us. It was the instinct of genius which led Dr William Budd to point out that the way to prevent the spread of scarlet fever is to attack the skin from the very first; to destroy the poison in the epidermis, or failing that, to prevent the breaking up and passage into the air of the particles of the detached epidermic scales. Oily disinfectant inunctions of the skin, and the most complete disinfection of the clothing which touches the skin of the patient, are the two chief means of arresting the spread of scarlet fever. The rules for smallpox are almost identical, though it is more difficult to carry them out; and they have to be supplemented by aerial disinfection. In enteric fever the immediate destruction of all particles of poison in the stools by very strong chemical reagents, and the prevention of the poison getting into sewers or drinking water or food, are the measures obviously demanded by the peculiarities of this special disease.

The more completely these points are investigated, and the more perfectly the breeding places in the body are known, the more precise will be our means of disinfection.

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* Bastian has, however, stated (Proceedings of Royal Society, No. 143, p. 224, March 1873) that bacteria and vibrios are killed at a much lower temperature; his experiments show that a brief exposure to a temperature of 70° C. (= 158° Fahr.) either killed the germs of bacteria, or completely deprived them of their powers of multiplication. The difference of the statements on such a point as this is remarkable. Tyndall (Proc. Roy. Soc. No. 178, p. 569) has since pointed out what appears to be, at least, a partial explanation of the above discrepancies. He shows, that whilst prolonged boiling failed to sterilise an infusion, successive heatings for a short time, even below the boiling-point, were successful. The explanation proposed is, that during the period of latency the spores are in a hard state capable of resisting high temperature, but that just before the period of active germination, they become softened, and therefore, amenable to the influence of heat. As, however, spores in various stages may exist in the same fluid, successive heatings are necessary so as to arrest each group at the proper time; but by repeating the heatings sufficiently often an infusion may be sterilised at a point below the boiling point of water.

To restrict the term disinfectant to chemical agents in the air seems far too narrow a view, and has the disadvantage of leading to attempts at destroying the poisons in what is the most uncertain and difficult method.*

### 3. *The Effect produced on the Contagia by Chemical Agents, or heat or cold, in different Diseases.*†

Our knowledge of this point is very imperfect, as it is necessarily derived simply from seeing if the spread of any contagious disease seems arrested by the disinfecting measures we employ. The experiment is a coarse one, and is conducted under all possible difficulties.

### *Disinfection in various Diseases.*

*Exanthemata, Scarlet Fever, and Rötheln.*—The points to attack are the skin and the throat. The skin should be rubbed from the very commencement of the rash until completed desquamation with camphorated oil, or oil with a little weak carbolic acid. The throat should be washed with Condy's fluid, or weak solution of sulphurous acid. Clothes to be baked, or to be placed at once in boiling water, to every gallon of which 2 ounces of commercial chloride of lime, or 1 ounce of sulphate of zinc, or ½ fluid ounce of chloride of zinc, is added. The clothes should not be washed at a common laundry.

Chlorine or euchlorine should be diffused in the air, the saucer being put some little distance above the head of the patient. Carbolic acid and ether or carbolic acid spray may be used instead.

In this, as in all cases, there can be no use in using aerial disinfectants, unless they are constantly in the air, so as to act on any particle of poison which may pass into the atmosphere.

*Smallpox.*—The skin and the discharges from the mouth, nose, and eyes

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* So also to restrict the term "disinfectant" to an oxidising agent cannot be right. A disinfectant is simply a destructive agent, and the destruction may doubtless be produced in different ways.

† With regard to the effect of chemical reagents on low forms of vegetable and animal life, the works of Sansom (The Antiseptic System, by A. E. Sansom, M.D. 1871); of Dr Dougall (On the Relative Power of various Substances in Preventing the Germination of Animalculæ, by John Dougall, 1871); and the Papers of Calvert (Proceedings Royal Society, vol. xx. p. 185), it need only be mentioned here that, according to Dougall (*op. cit.* table, p. 6), the most powerful agents in destroying "animalculæ" are the following substances:—Sulphate of copper, chloride of aluminium, chromic acid, and, bichromate of potassium, bichloride of mercury, benzoic acid, bromal hydrate, chloral hydrate, hydrocyanic acid, alum, hydrochlorate of strychnia, ferrous sulphate, arsenious acid, picric acid, and others which are less efficacious. Picot (Comptes Rendus, Dec. 1872) has lately stated that silicate of soda, even in very small quantity, arrests putrid fermentation and retards other fermentations, and is very useful in the treatment of blennorrhagic urethral discharge in women. It also opposes the transformation of glucose and of the glycogenous matters of the liver. If silicate of soda has such an effect, may not some of the other silicates be also active in this way, and may not the antiputrescent power of some soils be thus produced? Lex found the movements of Bacteria to be best arrested by chloroform, carbolic acid, prussic acid, and strong solutions of quinine, in the order named. Dr O'Nial (Surgeon-Major) has made many experiments on the time of appearance of Bacteria in extract of meat and other menstrua.† He found, like Dougall, the bichromate of potash to be the most powerful agent in preventing the appearance of Bacteria, and after it, but far below, is carbolic acid, yet neither were quite efficacious. The bisulphite of sodium was found to be of no value, and permanganate of potassium, though a good deodorant, had scarcely any restraining effect on the formation of Bacteria. Commercial chlor-alum was of little use, but a strong solution of chloride of aluminium was fairly effectual. The paper must be consulted for many details, but it shows clearly how little Bacteria can be influenced by our present modes of using these "chemical disinfectants." See also Baxter's Paper in the Reports of the Medical Officer of the Privy Council and Local Government Board, new series, No. vi. p. 216.

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† Army Medical Department Report for 1871, vol. xiii. (1873).

are to be attacked. There is much greater difficulty with the skin, as inunction cannot be so well performed. But smearing with oil and a little carbolic acid glycerine, or in difficult cases applying carbolised glycerine to the papules and commencing pustules, might be tried. The permanganate and sulphurous acid solutions should be used for the mouth, nose, and eyes. The clothing should always be baked before washing, if it can be done. The particles which pass into the air are enclosed in small dried pieces of pus and epithelial scales; and Bakewell, who has lately examined them, expresses great doubt whether any air-purifier would touch them. Still it must be proper to use euchlorine or carbolic acid. Iodine has been recommended by Richardson and Hofmann.

*Measles.*—Oily applications to the skin and air-purifiers, and chloride of zinc or of aluminium in the vessels receiving the expectoration, appear to be the proper measures.

*Typhus* (*exanthematicus*).—Two measures seem sufficient to prevent the spread of typhus—viz., most complete ventilation and immediate disinfection and cleansing of clothes. But there is also more evidence of use from air-purifiers than in the exanthemata. The nitrous acid fumes were tried very largely towards the close of the last century and the beginning of this, in the hulks and prisons where Spanish, French, and Russian prisoners of war were confined.* At that time, so rapidly did the disease spread in the confined spaces, where so many men were kept, that the efficacy even of ventilation was doubted, though there can be no question that the amount of ventilation which was necessary was very much underrated. Both at Winchester and Sheerness the circumstances were most difficult; at the latter place (in 1785), in the hulk, 200 men, 150 of whom had typhus, were closely crowded together; 10 attendants and 24 men of the crew were attacked; 3 medical officers had died when the experiments commenced. After the fumigations, one attendant only was attacked, and it appeared as if the disease in those already suffering became milder. In 1797 it was again tried with success, and many reports were made on the subject by army and naval surgeons. It was subsequently largely employed on the Continent,† and everywhere seems to have been useful.

These facts lead to the inference that the evolution of nitrous acid should be practised in typhus fever wards, proper precautions being taken to diffuse it equally through the room, and in a highly dilute form.

Hydrochloric acid was employed for the same purpose by Guyton-de-Morveau, in 1773, but it is doubtless much inferior to nitrous acid. Chlorine has been also employed, and apparently with good results.‡

In typhus it would seem probable that the contagia pass off constantly by the skin; at least, the effect of ventilation, and the way in which the agent adheres to body-linen, seem to show this. The agent is not also enclosed in quantities of dried discharges and epidermis, as in the exanthemata, and is therefore less persistent, and more easily destroyed, than in those cases. Hence possibly the greater benefit of fumigations, and the reason of the arrest by ventilation. The clothes should be baked, steeped, and washed, as in the exanthemata.

*Bubo Plague.*—The measures would probably be the same as for typhus.

*Enteric* (*typhoid fever*).—The bowels-discharges are believed to be the chief, if not the sole, agents in spreading the disease; the effluvia from them escape into the air, and will adhere to walls, and retain power for some time, or the discharges themselves may get into drinking water. Every discharge should be at once mixed with a powerful chemical agent; of those, chloride and sulphate of zinc have been chiefly used, but sulphate of copper (which Dougall found so useful in stopping the growth of animalculæ), chloride of aluminium,* or strong solution of ferrous sulphate (1 ounce to a pint of water), or carbolic acid.† After complete mixing, the stools must be thrown into sewers in towns; but this should never be done without previous complete disinfection. In country places they should be deeply buried at a place far removed from any water supply; they should never be thrown on manure heaps or into middens, nor into earth closets, if it can possibly be avoided. As the bedclothes and beds are so constantly soiled with the discharges, they should be baked, or if this cannot be done, boiled immediately after removal with sulphate or chloride of zinc. It would be less necessary to employ air-purifiers in this case than in others.

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* It was used at Winchester in 1780 by Carmichael Smith, and again at Sheerness in 1785. Smith published several accounts. An account of the experiment made at the desire of the Lords Commissioners of the Admiralty, by J. C. Smith, 1796.

† Chevallier, Traité des Désinfectants, pp. 39, 40.

‡ Ibid. pp. 14, 15.

*Cholera.*—There can be little doubt that the discharges are here also the active media of conveyance of the disease, and their complete disinfection is a matter of the highest importance. It is, however, so difficult to do this with the immense discharges of cholera, especially when there are many patients, that the evidence of the use of the plan in the last European epidemic is very disappointing.

The ferrous sulphate (green vitriol), which has been strongly recommended by Pettenkofer as an addition to the cholera evacuations, was fully tried in 1866 at Frankfurt, Halle, Leipzig, in Germany, and at Pill, near Bristol,‡ and in those cases without any good result. In other places, as at Baden, the benefit was doubtful. It seemed to answer better with Dr Budd and Mr Davies at Bristol, but other substances were also used, viz., chlorine gas in the rooms, and chloride of lime and Condy's fluid for the linen. On the whole, it seems to have been a failure.§ Ferric sulphate, with or without potassium permanganate, has been recommended by Kühne instead of ferrous sulphate, but I am not aware of any evidence on the point. Carbolic acid was largely used in England in 1866, and appeared in some cases to be of use, as at Pill, near Bristol, and perhaps in Southampton. It failed at Erfurt, but as it is believed the wells were contaminated by soakage‖ this is perhaps no certain case. Chloride of lime and lime were used at Stettin without any good result, and on the whole, it may be said that the so-called disinfection of the discharges of cholera does not seem to have been attended with very marked results. At the same time, it cannot be for a moment contended that the plan has had a fair trial, and we can easily believe that unless there is a full understanding on the part of both medical men and the public, of what is to be accomplished by this system, and a conscientious carrying out of the plan to its minutest details, no safe opinions of its efficacy or otherwise can be arrived at. It would be desirable to try the effect of chromic acid or bichromate of potassium.

With regard to air-purifiers, little evidence exists. Chlorine gas, diffused in the air, was tried very largely in Austria and Hungary in 1832, but without any good results. Nitrous acid gas was used at Malta in 1865, but apparently did not have any decided influences, although Ramon da Luna has asserted that it has a decided preservative effect, and that no one was attacked in Madrid who used fumigations of nitrous acid. But negative evidence of this kind is always doubtful. Charcoal in bulk appears to have no effect; Dr Sutherland saw a ship's crew severely attacked, although the ship was loaded with charcoal.

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* In speaking of chloride of aluminium, I refer always to the strong solution, and not to the commercial "chlor-alum," which, though useful in various ways, is yet a weak solution.

† Or a mixture of two or more (Budd). Be lavish (says Budd) in the use of chemicals rather than run the terrible risk of failing by default.

‡ Tibbets, Medical Times and Gazette, October 1867.

§ In my experiments on sewage putrefaction (Army Med. Reports, vol. viii. p. 318), ferrous sulphate had very little action in preventing putrefaction, and the Committee of the Berlin Medical Society declined to recommend it for cholera, as they found it did not prevent fermentative action.

‖ Ninth Report of the Medical Officer to the Privy Council.

Carbolic acid vapour diffused in the atmosphere was largely used in 1866 in England; the liquid was sprinkled about the water, and sawdust moistened with it was laid on the floors and under the patients. The effect in preventing the spread of the disease was very uncertain.

*Yellow Fever.*—In this case the discharges, especially from the stomach, probably spread the disease, and disinfectants must be mixed with them.

Fumigations of nitrous acid were employed by Ramon da Luna,* and it is asserted that no agent was so effectual in arresting the spread of the disease.

*Dysentery.*—It is well known that dysentery, and especially the putrid dysentery, may spread through an hospital from the practice of the same close stool or latrines being used. As long ago as 1807 fumigations of chlorine were used by Mojon,† to destroy the emanations from the stools, and with the best effects. The chlorine was diffused in the air, and the stools were not disinfected; but this ought to be done, as in enteric fever, and especially in the sloughing form. It is probable that carbolic acid in large quantity would be efficacious.

With respect to *Erysipelas*, *Diphtheria*, *Syphilis*, *Gonorrhœa*, *Glanders*, and *Farcy*, local applications are evidently required, and carbolic acid, in various degrees of strength, and the metallic salts, are evidently the best measures.‡

*Cattle Plague.*—The experiments made by Mr Crookes on the disinfectant treatment of cattle plague with carbolic acid vapour have an important bearing on human disease. Although the observations fall short of demonstration, there are grounds for thinking that when the air was kept constantly filled with carbolic acid vapour, the disease did not spread. So also euchlorine was employed in Lancashire by Professor Stone of Manchester, and with apparent benefit. Dr Moffat employed ozone (developed from phosphorus exposed to the air), and he believes with benefit.§ As such experiments are very much more easily carried out on the diseases of animals than on those of men, it is much to be wished that the precise effect of the so-called disinfectants should be tested by continuing the experiments commenced by Mr Crookes, not only in cattle plague in the countries where it prevails, but in episootic diseases generally.

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* Ann. d'Hygiène, April 1861.

† His words, as quoted by Chevallier, are interesting:—"The dysentery became contagious in the Hospital at Genoa; almost all the sick in my division, nearly 200, were attacked; and, as we know that this disease, when contagious, is communicated ordinarily from one person to another by the abuse which exists in all hospitals of making the same latrines serve for all the sick of a ward, I wished to see if fumigations of chlorine had the power of destroying these contagious exhalations. I therefore caused fumigations to be used twice daily in the latrines, and, in a few days, I was able to destroy that terrible scourge, which already had made some victims."

‡ Davaine finds iodine most powerful in destroying the infection of malignant pustule, [illegible] part being effectual. It may be injected into the skin without injury. (Comptes Rendus, Sept. and Oct. 1873). See also Report on Hygiene, Army Med. Reports, vol. xiv. in which its use in snake bite is suggested.

§ On Meteorology in reference to Epidemic and Sporadic Cholera, by F. Moffat, M.D., Hawarden, 1853.

It may be said in conclusion, that although positive evidence is so deficient, yet taking into consideration the decidedly great and known effect of many so-called disinfectants and air-purifiers on organic matters, and the fact that the infectious organic agencies are certainly easily destroyed in most cases (since free ventilation renders many of them inert, and few of them retain their power very long), it is highly probable that the specific poisons of the so-called zymotic diseases are destroyed by some of these chemical methods, and, at any rate, the careful and constant use of chemical agents for the destruction of the specific poisons in the excreta and discharges from the body, and when they pass into the air, is not only warranted, but should be considered imperative.

*Purification of Rooms after Infectious Diseases.*—In addition to thorough cleansing of all wood-work with soft soap and water, to which a little carbolic acid has been added (1 pint of the common liquid to 3 or 4 gallons of water), and to removal and washing of all fabrics which can be removed, and brushing of the walls, the room should be fumigated for three hours with either the fumes of sulphurous or nitrous acids. Both of these are believed to be superior to chlorine, especially in smallpox. All doors and windows and the chimney being closed, and curtains taken down, sulphur is put in a metallic dish, a little alcohol is poured on it, and it is lighted. The proportions should be 1 ℔ of sulphur for every 1000 cubic feet of space;* and in a long room, it is best to have the sulphur in two or more places.† After three hours the doors and windows should be opened, and kept open for twenty-four or thirty-six hours.

In white-washed rooms the walls should be scraped, and then washed with hot lime to which carbolic acid is added.

Mortuaries and dead-houses are best purified with nitrous acid (see p. 137).

*Purification of Clothes and Bedding.*—The best plan of doing this is certainly by the agency of heat. Dr Henry of Manchester, after showing that vaccine matter lost its power if heated to 140° Fahr. for three hours, proposed to disinfect clothing by dry heat. He disinfected scarlet fever clothing by exposure to 212° Fahr. for one hour; woollen clothing from plague patients, after being heated twenty-four hours from 144° to 167° Fahr., was worn with impunity by 56 healthy persons for fourteen days. Heat has been largely used to disinfect clothing by the Americans in their civil war, both in the form of dry heat and boiling water. It is believed that the cessation of the plague in Egypt, after St John's day, is due to the increased heat of the air; but possibly the hygrometric condition of the air may have more to do with this. It has also been surmised that the yellow fever poison is destroyed by an intense heat. Dr Shaw has collected the few facts which we know on this subject.*

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* Letheby gives a much larger proportion, viz., ½ ounce for every ten cubic feet. Even this is not an excessive amount. The quantity given in the text yields little more than one per cent. to the quantity of air. Thus:—1 ℔ of sulphur produces 11·7 cubic feet of sulphurous acid gas, and this diluted with 1000 cubic feet of air gives only 1·17 per cent. Half an ounce of sulphur yields 0·366 of a cubic foot of the gas, and this for 10 cubic feet of air gives 3·66 per cent. Baxter found that 0·194 to 1 per cent. destroyed the reproductive power of septic microzymes in an albuminous or aqueous medium, but with 0·58 per cent. the poison of infective inflammation was still active. Vaccine was destroyed after 10 minutes exposure to an atmosphere *saturated* with $SO_2$, whilst chlorine, or carbolic acid, took 30 minutes exposure. He concludes that for aerial disinfection $SO_2$ is the most convenient, but that the air should be saturated with it.

† A lamp has been proposed by Messrs Price & Co., in which bisulphide of carbon is burned. This seems, from experiments made at Netley by Professor Macdonald, to be efficacious, but the extreme inflammability of the substance may be a source of danger. An ounce burned in 55 cubic feet arrested the movements of putrefactive Bacteria in a meat infusion in a saucer; it also made the infusion acid, but after some hours Bacteria were again in active motion. The amount of $SO_2$ evolved in the air was 1·16 per cent.

*Disinfecting Chambers.*—Hot-air chambers, into which the linen and bedding are put, are now commonly used in baking infected clothes. The temperature ought not to be less than 220° Fahr., and probably a temperature of 250° Fahr. is desirable, but it must not be carried much above this, as some fabrics are singed.† The usual arrangement is a furnace with the smoke shaft passing under or on one side of a brick chamber, and with a hot-air blast from a shaft running through or under the fire into the chamber itself or into a passage below it, whence it passes into the chamber through a valve; an exit for the hot air is provided at the top of the chamber; the clothes are suspended in the chamber, at a little distance from the walls.

In other cases the bottom of the chamber is made of iron and the smoke flue passes beneath it; the iron becomes red hot, and is covered with sand, to prevent the clothes taking fire. Hot air is then poured into the chamber in the same way.‡ The disadvantage of the hot-air blast is the uncertainty and variation in the amount of heat.

Dr Ransom of Nottingham has devised a gas stove, viz., an iron box well covered with non-conducting material; in a channel leading to it a gas jet burns; by means of a regulator (modified from Kemp's regulator) the heat is kept uniformly, day and night, between 235° and 255° Fahr.; the hourly consumption of gas is 9 cubic feet for a small stove, which is sufficient for the hospital at Nottingham.§

Steam has been also used; and, at Berlin, a steam disinfecting chamber, proposed by Dr Esse,* is said to work well. This chamber is in the form of two iron cylinders of different diameters, one inside the other, and with walls strong enough to withstand the pressure of the steam; between the two cylinders steam enters from a neighbouring boiler, and heats the internal cylinder in which the clothes are suspended; at the top of the cylinder is a brass box which dips a little way down, and is pierced with holes at the bottom, so that the air of the inner cylinder can rise into it; in the box is a thermometer. The outer cylinder is covered with wood, and the top of the cylinder with felt, to economise heat; the steam, when it condenses in the space between the cylinders, flows out by means of a valve, which is lifted when the water reaches a certain point in the condenser. The clothes are introduced at the top, the lid of the cylinder being lifted up by a pulley; they are not allowed to touch the cylinder, but are suspended from wooden pegs. In an hour's time the heat can be brought to 90° R. (=234°·5 Fahr.). Another apparatus has been contrived by Esse for mattresses. It is an iron case with a spiral steam pipe in the centre, which heats with compressed steam (two atmospheres).†

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* Trans. Soc. Science Assoc. for 1864, p. 558.

† My friend, Dr Rausom of Nottingham, has made experiments on this point, and though when clothes are wet, higher temperatures can be used, yet when the clothes get dry, he found that fine fabrics begin to scorch at 255° or 260°.

In the Lancet (11 December 1876) I reported the results of some experiments undertaken at the request of the Director-General (A.M.D.). I found that woollen fabrics changed colour after 6 hours exposure to 212° Fahr., or two hours at 220° Fahr.; generally length of exposure and elevation of temperature are complementary. Cotton and linen showed signs of change of colour after 6 hours at 212° Fahr. or 4 hours at 220° Fahr. The Sanitary Regulations direct, that infected clothing, &c., shall be exposed to dry heat of 212° Fahr., for at least two hours. Dr E. Vallin, Professor of Military Hygiene at the Val-de-Grâce, has made further experiments on these points (De la Désinfection par l'air chaud, Mémoires de la Societé de Médicine Publique et d'Hygiène Professionelle, 1877). He finds that a piece of new white flannel is not more discoloured after 2 hours at 230° Fahr. than after one ordinary washing, and that even after three hours a piece already washed shows no change; 2 hours, however, at 240° Fahr. to 250° Fahr., show distinct change. He finds also, that cotton and linen do not change until they have been exposed for 2 hours to 257° Fahr. The strength of the material is not diminished (as shown by a dynamometer) until after 2 hours at 300° Fahr. Horse-hair becomes friable after exposure to heat, but this is chiefly an effect of drying, as it regains its ordinary condition in a short time, on reabsorbing moisture (Vallin, Lake). [F. de C.]

‡ At Liverpool the disinfecting chambers are 5 feet wide, 7 feet from front to back, and 6½ feet high to the spring of the arch. The walls and vaults are brickwork, the doors of wrought iron, fitting tightly into cast iron frames; in the floor there are double iron sliding gratings, and beneath it a hot-air passage. At the top of the arch, is an opening with an iron valve, for the escape of the air into an exhaust shaft which is carried into the chimney. The heating apparatus is a cast-iron cockle; two cast-iron smoke flues from it pass along the hot-air passage under the chambers into a chimney at the opposite end. Cold air is drawn along a brick flue underneath the floors of the stokehole into a space on each side of the cockle, and then into the passage under the chambers; it is admitted into chambers at pleasure through the sliding iron gratings in the floor. A damper at the entrance of the cold-air flue regulates the temperature. A temperature of 260° Fahr. has been registered in these chambers, and no less than 360° in a drying closet over the cockle.

§ Dr Ransom has introduced a modification (since an accident took place at the Southampton Infirmary, where all the clothes, &c., were consumed), by which a chain with a link of fusible metal is set free by the melting of the link at 300° F.; this closes a door, shuts off the gas, and prevents any further rise of heat.

The ordinary drying closet in a good laundry will sometimes give heat enough, but not always. A baker's oven can also be used on emergency.

*Soaking and Boiling Clothes.*—The boiling of clothes is not so good as baking, but still is very useful. It is desirable to add some chemical agent to the water, and chloride of lime is frequently used in the proportion of 1 gallon of the strong commercial solution to 20 or 30 gallons of water. Carbolic acid (1 part of pure acid and 2 parts of commercial acid to 100 of water) is also much employed. The German military regulations order the clothes to be laid for twenty-four hours in a solution of sulphate of zinc, in the proportion of 1 part to 120, or of chloride of zinc, in the proportion of 1 part to 240, and then to be washed with soap and water, if the clothes cannot be baked. The routine I have myself followed in the case of a large military hospital during war was to receive all dirty clothes into a large open shed, and to plunge them at once into tubs of cold water with chloride of lime. After twelve to twenty-four hours soaking, according to their condition, they were put into coppers and boiled, chloride of lime being again added to the water; they were then put into the washing-machine, and then dried and baked in a dry closet, heated to the highest point we could get, about 200° to 230° Fahr. If lice were very numerous, it was a good plan to bake the clothes before soaking; the lice were mostly killed, but some were only torpid, and were still living, after a temperature of probably 200° Fahr. They could, however, be shaken out of the clothes easily even if not dead.

*Fumigating Clothes.*—This is best done with sulphur, which may be used in the hot chamber, or the clothes are suspended in a small close chamber or large vat, and a large quantity of sulphur is set on fire, care being taken that the clothes are not burnt. Hair mattresses must be taken to pieces before fumigation if they are much defiled.‡

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* Deutsche Vierteljahrsch. für öff. Gesundheitspflege, band iii. p. 534 (1871).

† A steam cylinder is used at the London Fever Hospital, for disinfecting the feathers used as bedding.

‡ Directions for disinfection and fumigation are given in the Army Medical Regulations; see Sanitary Regulations" issued as a circular, $\frac{88407}{\frac{\text{Sanitary}}{4}}$, December 1876, section v. par. 32 to 46.

# CHAPTER XX.

# STATISTICS.

An accurate basis of facts, derived from a sufficient amount of experience, and tabulated with the proper precision, lies at the very foundation of hygiene, as of all exact sciences. Army surgeons have already contributed much important statistical evidence as to the amount and prevalence of different diseases, and it is evident that no other body of medical practitioners possess such opportunities of collecting, with accuracy, facts of this kind, both among their own nations and others. As they have to make many statistical returns, it seems desirable to make a few brief remarks on some elementary points of statistics, which are necessary to secure the requisite accuracy in collecting and arranging facts. But it is, of course, impossible for me to enter into the mathematical consideration of this subject; even were I competent, a separate treatise would be required to do justice to it.

## SECTION I.

## A FEW ELEMENTARY POINTS CONNECTED WITH GENERAL STATISTICS.

1. The elements of statistical inquiries are individual facts, or so-called numerical units, which having to be put together, or classed, must have precise, definite, and constant characters. For example, if a number of cases of a certain disease are to be assembled in one group with a definite signification, it is indispensable that each of these cases should be what it purports to be, an unit not only of a definite character, but of the same character as the other units. In other words, an accurate diagnosis of the disease is essential, or statistical analysis can only produce error. If the numerical units are not precise and comparable, it is better not to use them. A great responsibility rests on those who send in inaccurate statistical tables of diseases; for it must be remembered that the statist does not attempt to determine if his units are correct; he simply accepts them, and it is only if the results he brings out are different from prior results that he begins to suspect inaccuracy.[*]

2. These items or numerical units being furnished to the calculator, are by him arranged into groups; that is to say, he contemplates the apparently homogeneous units in another light, by selecting some characteristic which is not common to all of them, and so divides them into groups. To take the most simple case: A certain number of children are born in a year to a given population. The children are the numerical units. They can then be separated into groups by the dividing character of sex, and then into other groups by the dividing character of "born alive," or "still born," &c.

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[*] It is in vain to conceal the fact that many persons look at tables of diseases collected indiscriminately as worse than useless, from errors in diagnosis. Even in the army returns, which are all furnished by qualified practitioners, there is reason to doubt the correctness of the earlier tables especially. But it is believed that the army returns of diseases are now gaining in accuracy, and it cannot be too strongly urged on medical officers that perfect accuracy in diagnosis is a duty of the highest kind. It is much better to have a large heading of undetermined diseases than, when in doubt, to put a case of disease under a heading to which it has no unequivocal pretensions.

Or, a number of cases of sickness being given, these numerical units (all agreeing in this one point, that health is lost) are divided into groups by diseases, &c.; these groups, again, are divided into others by the character of age, &c., and in this way the original large group is analysed, and separated into minor parts.

This group-building seems simple, but to properly group complex facts, so as to analyse them, and to bring out all the possible inferences, can only be done by the most subtle and logical minds. The dividing character must be so definite as to leave no doubt into which group an unit shall fall; it must be precise enough to prevent the possibility of an unit being in two groups at the same time. This rule is of the greatest importance, and many examples could be pointed out of error from inattention to it.

Having decided on the groups, their numerical relations are then expressed in figures, for example :—

3. In order to express the relation of the smaller groups to the gross number of individual facts or units, a constant numerical standard must be selected, else comparison between groups of unequal numbers cannot be made. The standard universally adopted in medical statistics is to state this relation as a percentage, or some multiple of a percentage. So much per cent., or per 1000, or per 10,000, is the standard. This is got simply by multiplying the number of units in the smaller group by 100, and dividing by the total number of units. Thus, let us say there occur 362 cases of pneumonia; this is divided into two groups of recovered or died, say 343 recoveries and 19 deaths; and their relation may be expressed in one of two ways, viz., either by the relation of the deaths to the total number of cases, which will be—

$$\frac{19 \times 100}{362} = 5{\cdot}248 \text{ per cent.}$$

of mortality; or by the relation of the deaths to recoveries, viz.—

$$\frac{19 \times 100}{343} = 5{\cdot}54 \text{ per cent}$$

4. Having established that in a certain number of cases, divided into groups, the number in each group bears a certain proportion to the whole, how far are we justified in concluding that the same proportions will be repeated in future cases? This will chiefly depend on the number of the cases. If the number of cases from which one proportion has been taken is small, we can have no confidence that the same proportion will be repeated in future cases. If the number is large, there is a greater probability that the proportion in succeeding numbers of equal magnitude will be the same. The result obtained even from a very large number is, however, only an approximation to the truth, and the degree in which it approaches the truth can be obtained by calculation. The following rule is given by Poisson for calculating the limits of error, or, in other words, the degree of approximation to the truth :—

Let $\mu$ be the total number of cases recorded.
$m$ be the number in one group.
$n$ be the number in the other.

So that $m + n = \mu$.

The proportion of each group to the whole will be respectively $\frac{m}{\mu}$ and $\frac{n}{\mu}$, but these proportions will vary within certain limits in succeeding instances. The extent of variation will be within the proportions represented by

$$\frac{m}{\mu}+2\sqrt{\frac{2.m.n}{\mu^3}}$$

and*

$$\frac{m}{\mu}-2\sqrt{\frac{2.m.n}{\mu^3}}$$

It will be obvious that the larger the value of $\mu$ the less will be the value of $\sqrt{\frac{2.m.n}{\mu^3}}$, and consequently the less will be the limits of error in the simple proportion $\frac{m}{\mu}$.

An example will show how this rule is worked. The following is given by Gavarret ("Statisque Médicale," 1840, p. 284) :—

Louis, in his work on "Typhoid Fever," endeavours to determine the effect of remedies, and gives 140 cases, with 52 deaths and 88 recoveries. What is the mortality per cent., and how near is it to the true proportion?

$m = 52 =$ number of deaths.
$n = 88 =$ number of recoveries.
$\mu = 140 =$ total number of cases.

*i.e.*, 37 deaths in 100 cases, or more precisely 37,143 deaths in 100,000 cases. How near is this ratio to the truth? The possible error is as follows—the second half of the formula, viz.—

$$2\sqrt{\frac{2.m.n}{\mu^3}}$$

will be

$$2\sqrt{\frac{2\times 52\times 88}{(140)^3}}=0{\cdot}11550 \text{ to unity.}$$

(Or 11,550 in 100,000.)

The mortality being 37·143 per cent., or 37,143 deaths in 100,000 cases, in these cases, it may be in other 140 cases either

$37,143+11,550=48{\cdot}693$ per cent.
or $37,143-11,550=25{\cdot}593$ „

In other words, in successive 140 cases the mortality will range from 49 per cent. (nearly) to 26 per cent. (nearly), so that Louis' numbers are far too few to give even an approximation to the true mean.†

5. There being a number of facts, each of which can be expressed by a numerical value, an average or mean number is obtained by adding all the numerical values, and dividing by the number of facts.‡

In many cases the method by successive means is very useful. This consists in taking the mean of the mean numbers successively derived from a constantly repeated series of events (say the mortality to a given population

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[*] This is sometimes stated thus :—

$$\frac{p}{q}+\sqrt{\frac{8p(q-p)}{q^3}};$$

when $q$ = total number of events,
and $p$ = number of events in any particular direction.

[†] The relative values of two or more series are as the square roots of the numbers of observations. So also, by increasing the number of observations in any inquiry, the value (or accuracy) increases as the square root of the number.

[‡] The arithmetical mean is used in medical inquiries; but there are, in addition, the geometrical, harmonic, and quadratic means. For an account of these, and for many rules, I beg to refer to Dr Bond's translation of Professor Radicke's Essay, New Sydenham Society Publ. vol. xi.

yearly). Supposing, for example, the annual mortality in England to be, in successive years, 22, 23, 21, 26, 23, 21, 22, 28, 22, 21, per 1000 living, the successive means would be—

$$\frac{22+23}{2} \qquad \frac{22+23+21}{3} \qquad \frac{22+23+21+26}{4}$$

and so on, until the numbers are so great as to give every time the same result. It is useful to calculate the successive means in both the direct and inverse order, viz., from first to last, and then from last to first, *i.e.*, putting the two last together, then the three last, &c., so as to see if the variation was greater at the end of a series than at the beginning. The degree of uncertainty is then the mean variation between the successive means.*

A plan almost the same as this has been used; a certain number of facts being recorded, the sum is divided into two, three, or more parts, and it is then seen whether the results drawn from the lesser groups agree with that drawn from the larger group and with each other. If there is any great difference of results, the numbers of the lesser groups are not sufficient. In the instance given above, the mean of the ten years is 22·9; the mean of the first three years is 22; of the second three years is 22·33; of the third three years is 24. The term of three years is therefore far too short to allow a safe conclusion to be drawn. The mean of five years again is 23, and of eight years is 22·8, numbers which are much nearer each other and the mean of the whole ten years.

The application of averages when obtained is of great importance, but there is one usual error. The results obtained from an average (that is, from the mean result obtained from a number of units, not one of which perhaps is the same as the mean result, but either above or below it) can never be applied to a particular case. On either side the average there is always a range the value of which may be obtained by Poisson's rule as above, and the particular case may be at either end of the range. The use of the average is to apply it to an aggregate of facts. Then supposing it be founded on a sufficient number of cases, it will be exact.

6. In addition to averages, it is always desirable to note extreme values, that is, the two ends of the scale of which the average is the middle. To use Dr Guy's pointed expression, "averages are numerical expressions of probabilities; extreme values are expressions of possibilities."† In taking too great note of mean quantities, we may forget how great a range there may be above and below them, and it is by reminding us constantly of this that Poisson's rule is so useful.‡

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* To find the *mean error* :—1. Find the *mean* of the series of observations; find the *means* of all the observations *above* the mean, and subtract the mean from it, this gives the mean error in excess. 2. Find the *mean* of all the observations *below* the mean, and subtract it from the mean, this gives the mean error in deficiency. Add the two quantities, and take the half, this is the *mean error*.

To find the *error of mean square* :—Square each of the observations and add them together, subtract from this sum the square of the mean, multiplied by the number of observations, then, calling this remainder (*S*), and the number of observations (*n*), we have :—

$$\text{Error of mean square}, \quad . \quad . \quad . \left\{ \begin{array}{l} \text{Of a single measure}, \quad . \quad . \quad \sqrt{\dfrac{S}{n-1}}, \\[2ex] \text{Of the result}, \quad . \quad . \quad . \quad . \quad \sqrt{\dfrac{S}{n(n-1)}}. \end{array} \right.$$

* The *probable error* is obtained by taking two-thirds (nearly) of the mean error or error of mean square, the actual ratio being 1 : 0·6745.

† Cyclopædia of Anatomy and Physiology—Art. *Statistics*.

‡ In a good (that is a trustworthy) series, the extremes on the two sides of the mean will balance each other, the numbers being distributed according to the coefficients of a binomial;

7. Statistical results are now frequently expressed by graphic representations, a certain space drawn to scale representing a number. The most simple plan is that of intersecting horizontal and vertical lines.

Two lines, one horizontal (axis of the abscissæ), and the other vertical (axis of the ordinates), form two sides of a square, and are then divided into segments, drawn to scale—vertical and horizontal lines are then let fall on the points marked; the axis of the ordinates representing, for example, a certain time, and the axis of the abscissæ representing the number of events occurring at any time. A line drawn through the points of intersection of these two quantities forms a graphic representation of their relation to each other, and the surface thus cut can be also measured and expressed in area if required, or the space can be plotted out in various ways, in columns, pyramids, &c. In the same way circles cutting radii at distances from the centre drawn to scale are very useful; the circles marking time (in the example chosen), and the radii events, or the reverse. Such graphic representations are most useful, and allow the mind to seize more easily than by rows of figures the connection between two conditions and events.

Generally speaking, it may be said that the amounts of sickness and mortality in different bodies of men or in the same body of men at successive periods, show such wide variations, that the mean error is always very great, and it requires a very large number of cases, and an extended period, to deduce a probable true mean. For this reason it is necessary to be cautious in apportioning blame or credit to persons, or to special modes of treatment, unless the numbers are very large and accordant. The circumstances influencing the result are, in fact, very numerous, and the proper estimation of a numerical result is only possible when it is considered in reference to the circumstances under which it occurs.

The most important statistical inquiries applied to health are—

1. *Births to Population.*—To obtain all these elementary facts, an accurate census and proper registration are required. It is only within the last few years that the most civilised nations have commenced these inquiries.

2. *Relative Number of Live and Still-Born, of Premature and Full-Grown Children.*

3. *Number of Children Dying in the First Year, with Sub-Groups of Sex and Months.*—There are two great periods of mortality in the first year, viz., in the first week, and at the time of weaning, about the seventh month.

4. *Amount of Sickness to Population.*

   (*a*) Number constantly sick, grouped according to sex, age, occupation, and diseases.

   (*b*) Average duration of sickness, &c.

5. *Amount of Yearly Mortality in a Population, or Deaths to Population.*—The deaths are generally expressed as so many deaths to 1000 or 10,000 living; but the deaths can be calculated in relation not only to the number living at the end of the time, but to that number *plus* a certain addition to be made on account of those persons who lived during part of the time, but died before its close. But the difference is not material. Grouped according to sex, age, &c.

6. *Mean Age at Death of a Population is the Sum of the Ages at Death, divided by the Deaths.*—The mean age at death expresses, of course, the expectation of life at birth, or the mean lifetime. It is no very good test of the health of a people, as a great infant mortality may reduce the age, though the

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whose exponent is the number of possible events in the series (see Quetelet, on Probabilities; Airy, on the Theory of Errors of Observation; Merriman, Theory of Least Squares; De Chaumont, Lectures on State Medicine).

health of the adults may be extremely good. The mean age of death in England is about 40 years.

7. *Mean Duration of Life* (*vie moyenne*).—This is the expectation of life at birth; at any other age than birth, it is the expectation of life at that age (as taken from a life-table) added to the age. It is no good test of sanitary condition or health.

8. *Probable Duration of Life* (*vie probable*; probable lifetime) is the age at which a given number of children born into the world at the same time will be reduced one-half.

9. *Expectation of Life, or Mean Future or After Lifetime.*—This is the true test of the health of a people. It is the average length of time a person of any age may be expected to live; and in order to construct it, we must know the number of the living, their ages, the number of deaths and the ages, and the other changes in the population caused by births, emigration, immigration, &c. It does not, of course, follow that any particular person will live the time given in such a table; he may die before or after the period, but taking a large number of cases, the average is then found to apply. Life-tables show at a glance the expectation of life at any age.

After the first year the chances of living increase up to the fourth year; the fifth year is nearly as good, and then the chances of life lessen, but at first slowly, and then more rapidly; from 5 to 40 years of age the expectation of life lessens in the ratio of from 2½ to 3½ or 3¾ years for each quinquennial period.

*England.**

| Ag. | Males. | Females. | Age. | Males. | Females. | Age. | Males. | Females. |
|---|---|---|---|---|---|---|---|---|
| 0 | 39·91 | 41·85 | 10 | 47·05 | 47·67 | 70 | 8·45 | 9·02 |
| 1 | 46·65 | 47·31 | 20 | 39·48 | 40·29 | 80 | 4·93 | 5·26 |
| 2 | 48·83 | 49·40 | 30 | 32·76 | 33·81 | 90 | 2·84 | 3·01 |
| 3 | 49·61 | 50·20 | 40 | 26·06 | 27·34 | 95 | 2·17 | 2·29 |
| 4 | 49·81 | 50·43 | 50 | 19·54 | 20·75 | 100 | 1·68 | 1·76 |
| 5 | 49·71 | 50·33 | 60 | 13·53 | 14·34 | | | |

## SECTION II.

### ARMY STATISTICS.†

At the close of the Peninsular war in 1814, Sir James M'Grigor commenced the collection of the statistics of disease and mortality in the English army, and during the course of the next twenty years a great amount of valuable evidence was accumulated. In 1835 Dr Henry Marshall (Deputy-Inspector of Hospitals, and one of the most philosophical surgeons who have ever served in the English army) commenced to put these returns into shape, and the late Major-General Sir Alexander Tulloch, K.C.B. (at that time a lieutenant in the 45th Regiment, employed in the War Office), was associated with him. In the following year, on the retirement of Dr Marshall, Dr Balfour, the late head of the Statistical Branch of the Army Medical Department, was appointed as his successor, and in conjunction with Sir A. Tulloch, brought out the series of reports on the health of the army which have had such influence, not merely on the causes of the sickness and mortality among soldiers, but indirectly on those of the civil population also. In 1838–1841, reports were issued of the following stations:—United Kingdom, Mediterranean, and British America, West Indies, Western Africa, St Helena, Cape, Mauritius, Ceylon, and Tenasserim.

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* Abridged from Dr Farr's Life Tables. Some interesting information will be found in Statistics of Families, by C. Ansell, jun., 1874.

† The short summary of the history of the Army Statistical Reports is chiefly taken from Dr Balfour's account, in the Army Medical Report for 1860, p. 181.

These returns included the years 1817–1836. In 1853 another report, containing the stations of the troops in the United Kingdom, Mediterranean, and British America, including the years 1836–1846, was prepared by the same gentlemen.

In these reports, in addition to the statistical analysis, short but most graphic and comprehensive topographical and climatic accounts of the different stations were given.

The effect of these several reports, and especially of the earlier issues, was to direct the attention of the Government, both to the fact of an enormous sickness and mortality, and to its causes, and then commenced the gradual series of improvements which at a later period were urged on by Lord Herbert with so much energy.

The Russian war of 1854–1855 prevented any further publication until 1859, when yearly reports were commenced by Dr Balfour, and have been regularly issued since. In the report for 1860 Dr Balfour has given a summary of the earlier and later mortality of the different stations before and after 1837, which shows a remarkable difference in favour of the later periods as regards both sickness and mortality.[*]

### SUB-SECTION I.

With respect to soldiers *in time of peace*, the statistical evidence is required to show the amount of benefit the State receives from its soldiers, and the amount of loss it suffers yearly from disease. Tables should therefore show—

1. The amount of loss of strength a definite number of men in each arm of the service suffers in a year—

(*a*) By deaths, or, in other words, the mortality to strength.

(*b*) By invaliding from disease,[†] for if this is not regarded, different systems and modes of invaliding may entirely vitiate any conclusions drawn from the mortality.

The groups thus formed must be again subdivided, so as to show—

(*a*) The causes of death or invaliding.

(*b*) The ages of those who die or who are invalided.

(*c*) Their length of service. It is of great importance to determine the influence of service in every year, and these groups should be again divided by ages.

2. The loss of effective service a definite number of men—say, 1000 in each arm—suffers during a year. This is best expressed as follows:—

(*a*) The total number of cases of disease in a year, *i.e.*, the number of admissions to hospital per annum. It must be understood that this does not express the number of men admitted, as one man may be admitted two, three, or even ten times with the same disease; each admission counts as a fresh case. It would be very important to have another table showing the number of men admitted for different diseases, or, in other words, the number of cases of re-admission for the same disease.

(*b*) The number constantly sick on an average. This is often called the sick population, and is obtained most easily in army hospitals by dividing the number of diets issued in a year by the purveyor by 365, or adding all the "remaining" on the daily or weekly states together, and dividing by 365 or 52, as the case may be.

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[*] In the chapter on INDIA, I have mentioned the chief statistical papers which refer to that country.

[†] Loss by purchase of discharge, expiration of term of service, imprisonments, and dismissals from the Army, must also be put under separate headings; but the medical officer has nothing to do with this point, except to see that such cases are not confounded with invaliding from disease.

(*c*) The total number of days lost in a year to the service by illness by the 1000 men, and of the number of days per head. The number of the sick population (that is, the number constantly sick out of, say 1000 men) multiplied by 365 and divided by 1000, or by the number furnishing the sick, whatever that may be, gives these facts.

(*d*) The mortality in relation to sickness.

The group constituted by the sick must then be subdivided by diseases, and lesser groups must be made by distributing the causes of sickness and deaths under ages and length of service.

There are a few points which require attention. The amount of sickness and mortality is calculated on the mean strength, that is, the number of men of a regiment present at a certain station on the muster days divided by the number of muster days. But it must be understood that this includes the sick men in hospital as well as the healthy men, and therefore does not perfectly express the amount of disease among the healthy men. Also sometimes the muster rolls of a regiment include men on detachment at some distance, whose sickness is not attributable to the headquarter station. The French, in their Army Statistical Returns, make two headings, one of "mean strength" (*effectif moyen*), and the other of "present" (*présents*), the men in hospital not being included in the latter. Moreover, in the French Army, nearly one-sixth are always absent on leave; and the deaths of those on leave are included among the army deaths, but the sickness is not so. Consequently, sickness has to be calculated on the number not on leave; deaths, on the total strength. In the French army officers are included with the men; in the English, separate returns are made.

It is often difficult to get the mean strength if there are many changes of troops, and instances of erroneous calculations from this cause are not uncommon.*

In calculating also the effect of age and length of service upon disease and mortality, it is necessary to know not only the ages and length of service of the sick men, but of the healthy men also, and to calculate out the proportion of the sick to the healthy at that particular age or length of service, otherwise very erroneous conclusions might be drawn. For example, it might appear that sick men under nineteen years of age were very numerous in proportion to other years, but in a young army the greater number of the force might be of this age. Care is necessary in all these points to arrive at correct conclusions.

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* I subjoin one which Dr Balfour has given. It will be seen that an unhealthy station (Masulipatam) in India is credited with a much greater degree of health than it really was entitled to, and the annexed extract from Dr Balfour's paper (Edin. Med. and Surg. Jour. No. 172) shows clearly how the mistake arose:—

"The [Madras] Medical Board, in submitting to Government the table from which these figures are computed, stated that the ratio of mortality among all the European regiments in the Presidency, from January 1818 to December 1819, was 5·690 per cent.; whilst that of the regiments at Masulipatam, from 1818 to 1832 inclusive, was 5·100 per cent. They then add—'The rate of mortality having been somewhat lower than throughout the rest of the Presidency for such a period, gives reason to conclude that the station cannot be considered under ordinary circumstances as unhealthy.' Now, the Board appears to have arrived at this conclusion from an error in the mode of calculating the ratio. In several of the years between 1818 and 1832 the regiments were quartered at Masulipatam during part of the year only. It must be obvious to any one conversant with the principles of statistics, that in such a case a proportion of the annual strength only should be taken corresponding with the period for which the regiment was quartered there. Thus, if the period was nine months, the sickness and mortality should be calculated on three-fourths of the strength; if eight months, on two-thirds, and so forth. The Board, however, have made the calculation in every instance on the average annual strength without any such deduction. Had the necessary correction been made, the deaths from 1818 to 1832 would have been found to average 6·394 per cent. annually, instead of 5·100, as above stated."

### SUB-SECTION II.—STATISTICS IN WAR.

*In time of war* the statistics must be slightly altered in form, though the same in principle. The object is to show as completely as possible to the General in command what amount of loss his army is suffering at the moment, and to what extent it may be expected to suffer, and also what are the causes of such sickness.

The sickness here must not only be calculated on the mean strength (which will include the men in hospital), but also on the healthy men, or those actually under arms and effective. If the sick are counted in the strength, the sickness of the army may be much understated. What a General wants to know with regard to sickness will be these points:—

1. How many men am I losing daily from the rank and file actually serving with the colours?
2. How many are replaced by discharge from hospital?
3. What is the balance, gain or loss?
4. If my effective force loses daily, when this balance is struck, such a percentage, what will be its loss of strength in a week, in four weeks, in six weeks? &c.
5. What are the causes, *i.e.*, what are the diseases which are causing this sickness, and how are they affected by special circumstances of age, particular service or arms, or other causes?

The mortality in war should be calculated on the mean strength, that is, on the total number of healthy and sick, and also on the sick alone, so as to represent both the loss of the army and the fatality of the sickness.

# BOOK II.

## THE SERVICE OF THE SOLDIER.[*]

It is now necessary to consider a little more particularly the nature of the service of the soldier, and the influence it has on him. A recruit entering the army from civil life comes under new conditions, which will require to be shortly enumerated.

## CHAPTER I.

## THE RECRUIT.

In the English army, young men are enlisted at eighteen years of age,[†] unless they are intended for drummers. They must be of a certain height, which is fixed by regulation from time to time, according to the particular arm, and to the demands of the service. There must also be a special girth of the chest, which is in proportion to the age and height.

In time of war, the measurements are reduced according to the demand for men; and even in time of peace, the necessary height of the infantry recruit, usually 65 or 66 inches, has been sometimes only 5 feet 4 inches.[‡] Before the enlistment is completed, the recruit is examined by a medical officer, and then by the surgeon-major of the recruiting district, according to a scheme laid down in the Medical Regulations.[§] The scheme is a very good one, and aims at investigating, as far as can be done, the mental condition; the senses; the general formation of the body, and especially of the chest; the condition of the joints; the state of the feet; the absence of hernia, varicocele, piles, &c.; and the condition or physical examination of the heart, lungs, and abdominal organs generally.[‖] A certain girth of chest according to the height is required.[¶]

After joining his regiment he is again examined, and may be rejected if any defect is discovered. Rejections may take place then either at the primary or secondary inspection.

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[*] Medical officers entering the army will find a great deal of useful sanitary information and details of duty bearing on health in Sir Garnet Wolseley's Soldiers' Pocket Book for Field Service.

[†] In reality, they sometimes enlist under this age.

[‡] By the last General Order, 15th Sept. 1877, it is raised to 5 feet 5 inches (except for the Rifles) from 5 feet 4½, which was the height fixed in 1876.

[§] For a full account of the system of recruiting, the mode of examination, and much useful information on disabilities, see a paper by Dr Crawford in the Army Medical Report for 1862.—*Blue Book*, 1864.

[‖] As the Medical Regulations are in the hands of all medical officers, it is unnecessary to go into more detail on this point. My colleague, Professor Longmore, uses in the Army Medical School a set form of examination, which renders it almost impossible that any point should be overlooked.

[¶] At present, 34 inches for 65 in height.

Both the average weight and height, especially the latter, will vary with the demand for men.

The trades of the men furnishing the recruits must also vary greatly from year to year.*

The total number of rejections, either at once or after re-examination by a second medical officer, on various grounds, of men brought by the recruiting serjeant to the medical officer, varies somewhat from year to year.

About two-fifths of the rejections arise from causes connected with general bad health or feeble constitution, and one-fifth from causes affecting the marching powers of the men (Balfour).

In the French army, the height was fixed in 1860 at 69 inches (1·76 metres) for the carabiniers, and 61½ inches (1·56 metres) for the infantry of the line.

In 1872 the minimum for the cuirassiers was reduced to $1^{m}$·70 (67 inches) without any fixed maximum.

In 1868 the minimum for the line was reduced to $1^{m}$·55 (61 inches), and still further in 1872 to $1^{m}$·54 (60½ inches).†

The rejections in the French conscription include men rejected for insufficient height, as well as reasons of health.‡

After the recruit has been enlisted and approved, he joins his depôt or his regiment; receives his kit, which he subsequently in part keeps up at his own cost; and is put on the soldier's rations. He enters at once on his drill, which occupies from 3½ to 4½ hours daily. Wherever gymnasia are established, he goes through a two-months' course of gymnastic training for one hour every day. He then goes to rifle drill, which lasts about six weeks, and then joins the ranks. After the rifle drill, he has another month's gymnastic training, and is then supposed to be a finished soldier.

Such being the system, it will be desirable to consider certain points.

1. *The Age of the Recruit.*—Strong opinions have been expressed by Ballingall (English army), Levy (French army), Hammond (American army), and other army surgeons, that the age of 17 or 18 is too low—that the youngest recruit should be 20 or 21 years of age.

This opinion is based both on actual experience of the effect produced on boys of 17 to 20 when exposed to the hardships of war, or even to heavy duty in time of peace, and on a physiological consideration of the extreme immaturity of the body at 18 years of age.

With regard to the first point, there is no doubt that to send young lads of 18 to 20 into the field, is not only a lamentable waste of material, but is positive cruelty. At that age such soldiers, as Napoleon said, merely strew the roadside and fill the hospitals. The most effective armies have been those in which the youngest soldiers have been 22 years of age.

With regard to the second, it is also certain that at 18 the muscles and bones are very immature, and, in fact, it is not till 25 years of age, or even later, that epiphyses of the bones have united, and that the muscles have attained their full growth.§

The epiphyses of the transverse and spinous processes of the vertebræ hardly commence to ossify before 16 years of age, and it is not till after 20 years that the two thin circular plates form on the body of the vertebræ. The whole process is not completed till close on the 30th year. The consolidation of the sacrum only commences at the 18th year, and is completed from the 25th to the 30th year. The fourth and third bones of the sternum are only united between the 20th and 25th years, and the second is not united to the third bone before the 35th year. The epiphyses of the ribs commence to grow between the 16th and the 20th years, and are completed by the 25th year. The epiphyses of the scapula join between the ages of 22 and 25. The epiphysis of the clavicle begins to form between the 18th and 20th years. The internal condyle of the humerus unites at 18, but the upper epiphysis does not join till the 20th year. The epiphyses of the radius and ulna, the femur, the tibia, and fibula, are all unjoined at 18 years, and are not completely joined till 25 years. The epiphyses of the pelvic bones (viz., crest of ilium, spine, and tuberosity of the ischium) begin to form at puberty, and are completed by the 25th year.*

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* The average weight and height of the recruits, and the classes from which they are drawn, are carefully given by Dr Balfour, and Sir A. D. Home, in the Army Medical Department Reports.

† Morache, Traité d'Hygiène Militaire, 1874.

‡ Sistach, Recueil de Mém. Mil. 1861, Nov. p. 353.

§ See Aitken's Growth of the Recruit and Young Soldier, 1862.

That the muscles are equally immature is just as certain; they grow in size and strength in proportion to the bones.

These facts show how wrong it is to expect any great and long-continued exercise of force from men so young as 18 and 20, and what will be the inevitable consequences of taxing them beyond their strength.

Are we, then, to conclude that the soldier should not be enlisted before 20?

It appears to me that the case stands thus. If the State will recognise the immaturity of the recruit of 18 years of age, and will proportion his training and his work to his growth, and will abstain from considering him fit for the heavy duties of peace and for the emergencies of war till he is at least 20 years of age, then it would seem that there is not only no loss, but a great gain, by enlisting men early. At that most critical period of life the recruits can be brought under judicious training, can have precisely the amount of exercise and the kind of diet best fitted for them, and thus in two years be more fully developed, and be made more efficient, than if they had been left in civil life.

2. *The Height and Weight of the Recruit.*—The desire of almost all military officers is to get tall men. The most favoured regiments, especially the cavalry, get the tallest men. It has been recommended both that shorter men should be generally taken, and that the infantry should have the tallest men. The last point is one for military men to determine, and must be decided by considerations of the respective modes of action of cavalry and infantry.

The first point is entirely physiological, and opens a difficult question.

What is the height, at 18 years of age, which is attended with the greatest amount of health, strength, and endurance, or is it possible to fix such a standard?

Tables of average height and weight have been compiled by Quetelet, and much used, and lately somewhat similar tables have been framed by Danson, Boyd, and Liharzik.†

With regard to all of these it may be said that the observations (however numerous) are yet too few for such a large question, and that the influence of race has been too little regarded.

Boyd gives the height at 18 years at 60·4 inches, and at 25 years at 67 inches, and Liharzik at the same ages gives 64·17 and 68·9 inches. The English Army Returns (1860–67) give the heights of the recruits, but it must be understood that we cannot deduce the mean height of the population from these figures, as the shorter men are not taken as recruits.

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* See Aitken's Growth of the Recruit, p. 37, and Quain's Anatomy, for still fuller details.

† Liharzik's number professes to be based on a law induced from great numbers of measurements in different animals.

Although the numbers are not very accordant, we may perhaps assume that at 18 the average height will be something near 64 or 65 inches, and the average weight 124 ℔.

But the difficulty of the case only commences here; taking the age at 18 (for over 20 the case is simple), what is the range above and below the average which is consistent with perfect health and growth? How far is it safe to apply an average to an individual? Will not an excess of weight and height imply that an individual comes of a larger race, or has been better fed and nourished, and is so far a stronger man than he who only just reaches the average?*

The range, in fact, appears to be very great, as much as six inches above and below the mean (Danson); *i.e.*, a boy at 18 may be 58 or 71 inches tall. But are these extremes consistent with perfect health, such as we demand in a recruit? It seems very doubtful if they are.

It may be well to put the same question in rather a different way. In the English army the minimum height has been always (except in times of great emergency) above the mean height of the population at that age. Has the State, then, secured a larger-framed and more powerful set of men by only taking those who are above the mean height, or has it unnecessarily limited its choice?

The experience of other armies cannot answer this question. The French height of infantry, which was (before 1868) 61½ English inches, or 2½ below the mean, is now 60½, or 3½ below the mean. The Austrian height for infantry is 61 inches; in the German army the least height (in English inches) of the recruits for the cuirassiers is 65·7 inches, and the greatest 68·9 inches; for the light cavalry (hussars and dragoons), the least height is 63·8, the greatest 67·7 inches. In the Jäger battalions the height is 61·8 inches (English), and not more than 68·9 inches. In the infantry (not Jäger) the least height is 61·8 inches.† In the Northern American army the height of the infantry was, in 1863, fixed at 63 inches (Hammond), but men were really taken as low as 60 inches.‡

It is therefore clear that the great military nations go 2 inches or even more below the mean height of the population at the recruiting age, and find no injury to the quality of their soldiers, and it would certainly appear unnecessary that the English should fix their standard (as has been sometimes done) at 1 inch above the mean height for infantry, and 2 or 4 inches for cavalry. But this does not settle the question, as it may still be argued that the taller men are most desirable when they can be procured, although shorter men may answer very well when others cannot be obtained. I really know of no good evidence which can settle this question.

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* M. Bernard (Rec. de Mem. de Méd. Mil. Mai 1868, p. 371) gives the mean age of 400 men of the foot Chasseurs of the Guard as 30¼ years; the mean circumference of the chest 34·6 inches; the mean height 64·8 inches; and the mean weight 142·4 ℔ avoir. There were only 9 men between 18 and 21 years of age; the mean girth was 33 inches, the height 66 inches, and the weight 138 ℔ avoir. So that those 9 men were actually taller than the mean. This shows how small numbers might mislead.

† Below this, none are taken, except for service without arms. Law of 8th Sept. 1875, see Roth. and Lex. *op. cit.* Bd. iii. p. 161.

‡ The minimum height of the Roman soldier in the time of Vegetius was 64·6 inches; this was nearly 3 inches below the minimum height in the time of Marius. As armies increased in proportion to the population the minimum necessarily diminished; in 1691 the minimum for French Infantry was 1m. 705 (67·2 inches) in time of peace, and 1m. 678 (66 inches) in time of war. By 1813 it had fallen to 1m. 52 (59·9 inches); in 1818 it was 1m. 57 (61·8 inches), since which time it has fluctuated between 1m. 56 (63 inches) and 1m. 54 (60½ inches) at which it at present stands, see Morache, *op. cit.* p. 87.

The best rule to guide us is that given by Dr Aitken, viz., to take into consideration the three points of age, height, and weight, and if either in weight or height, or both together, there is any great divergence from the mean, then something wrong will probably be found. But as long as weight and height are in accord, the taller and heavier the man the better, as a rule.

One point is, however, quite clear. When the height is much below the mean, the bodily development generally is bad. Hammond states that, in the American war, men of less than 5 feet have broken down by a few weeks' campaigning, while men of 5 feet have stood the work well. Probably 62 inches at 18 years of age, and 112 ℔ to 116 ℔ weight, should be a minimum, even in times of the greatest pressure. So also a very great height at 18 years of age is objectionable, and anything over 67 inches at that age should be looked on with great suspicion. As a rule, also, adult men of middle size (67 to 69 inches) appear to bear hard work better than taller men.*

With regard to weight alone, the rule is simple. Unless there be any great disproportion in height, the heavier the recruit is the better; this will be found a rule with very few exceptions.

3. *The Physical Training of the Recruit.*—A great improvement has been introduced by the late order that each recruit shall have three months' gymnastic training. If properly done, this will have a most beneficial effect. The medical officer will have power to continue this if necessary, and care should be taken to use this power (see chapter on GYMNASTIC TRAINING for the points to be attended to by the medical officer).

4. *The Mental Training.*—Since the introduction of rifle practice, the trade of the soldier has become much more interesting to him; he is now taught scientifically how to manage his arm, and learns to take interest in his shooting. It would be most desirable to give him some knowledge of the Military Art, and of the object of the manœuvres he goes through. A military literature fitted for the private soldier is still wanting. It is also very important to train him for the field, and to teach him to perform for himself all the offices which in time of war he will have to do—not merely trench work, but hutting, cooking, washing and mending his clothes, as in time of war (see WAR). It is too late, at the commencement of a campaign, to begin these necessary parts of a soldier's education; they should form part of his training as a recruit; and if he is excused guard and other duties during his first year, there would be ample time.

Great attention is now being directed to the importance of soldiers keeping up their trades, or learning some trade if they have none. Such a system occupies men, makes them contented, keeps them from dissipation, and opens a career for them when they leave the army. Instead of interfering with their military training, it can be made to subserve it, and possibly might be found to be advantageous to the State, even in a pecuniary point of view. The recruit then would have to keep up or learn his trade.

5. *The Moral Training.*—The recruit, on entering the army, is brought under moral influences of a strong kind. A discipline always rigorous, and sometimes severe, produces often a ready obedience and a submission of character, and, when not carried too far, greatly improves him. At the same time, independence is preserved by the knowledge which the soldier has of his rights and privileges, and the result is a manly, conscientious, and fine character. But occasionally, a too sensitive nature on the part of the recruit,

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* For some useful information on these points, see Morache, *op. cit.*, Roth. and Lex. *op. cit.* and Auguste Jansen, 'Etudes sur la taille, le périmètre de la poitrine et le poids des recrues,' Extrait des Archives Médicales Belges, 1877.

or a discipline too harsh or capricious on the part of his officers, produces very different results, and the soldier becomes cunning, artful, and false, or morose and malicious. The two characters are often seen well marked in old soldiers, and no contrast can be greater than between the two. A heavy responsibility rests, then, with the officers of the army who have power thus to influence, for good or evil, natures like their own.

The influence of companionship is also brought to bear on the recruit, and is fraught with both good and evil. The latter probably predominates, though there are many excellent, high-minded, and religious men in the army. Indeed, in some regiments the proportion of steady religious men is perhaps beyond the number in the analogous class in civil life. But if the influences be for bad, the recruit soon learns some questionable habits and some vices.

Thus he almost invariably learns to smoke, if he has not acquired this habit before. It is indeed remarkable what a habit smoking tobacco is in every army of Europe; it seems to have become a necessity with the men, and arises probably from the amount of spare time the soldier has, and which he does not know what to do with. A recruit, on joining, finds all his comrades smoking, and is driven into the habit.

The discussion on the effects of tobacco does not seem to have led to any clear conclusions. The immoderate use brings many evils to digestion and circulation especially. But no great evils appear to result from the *moderate* use, though no good can be traced to it. In moderation it has not been proved to lessen appetite, to encourage drinking, or to destroy procreative power. But, on the other hand, it probably lessens bodily, and perhaps even mental activity. It is certainly remarkable how uniformly the best trainers prohibits its use, and men of the highest physical vigour are seldom, I believe, great, and often are not even moderate smokers. As it is of no use, and indeed injurious, by bringing men under the thraldom of a habit, it seems very desirable to discourage it. But in the army it seems useless to fight against this custom, nor is it indeed one which is sufficiently injurious to be seriously combated, except for one reason. In time of war, the soldier often cannot obtain tobacco, and he then suffers seriously from the deprivation. The soldier should have no habits which he may be compelled to lay aside, and which it would pain him to omit.

A much more serious matter is the vice of drinking, which many recruits are almost forced into, in spite of themselves. The discipline of the army represses much open drunkenness, though there is enough of this, but it cannot prevent, it even aids, covert drinking up to the very edge of the law. Formerly, a most lamentable canteen custom made almost every man a drunkard, and a young boy just enlisted soon learned to take his morning dram, a habit which, in civil life, would mark only the matured drunkard. Now, happily, spirits are not sold in the canteens, and no regulation thrusts raw spirits down a man's throat. Drinking is, however, still the worst vice in the army, and that which strikes most of all at the efficiency of the soldier. Great efforts have been, however, made by the military authorities to check this vice, and I believe there is little doubt that the army is gradually becoming more temperate.

Another vice is almost as certainly contracted as smoking by the recruit. Probably, before enlistment, he has led no very pure life, but when he enters the army, he is almost sure to find his moral tone higher than that of some of his new associates. A regiment, in fact, is composed of young men with few scruples and small restraints. Prevented from marriage, and if of long service, not able, indeed, to look forward to it; often tempted by low prostitutes, it is no wonder if, to the extent of his means, the soldier indulges in promiscuous sexual intercourse. He does this, in fact, to excess, and the young recruit is led at once into similar habits. That many recruits are most seriously injured by this habit, even if they neither contract syphilis nor gonorrhœa, is certain. The remedies have already been discussed.

It has also been supposed that solitary vice is particularly rife in armies. I am unaware of any evidence on this point.

6. *The Amount of Sickness and Mortality suffered by the Recruit during the First Six Months and Year of Service.*—This is an extremely important matter, but at present we are not able to answer the question for the English army.

In the French army,* the amount of sickness among soldiers under one year of service is more than one-third greater than among the army generally; this is partly caused by slight injuries, though not solely, for the admissions to hospital are nearly one-fourth more among them than in the army at large.

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* Statistique Médicale de l'Armée pendant l'Année 1862. Paris, 1864, p. 11. Ibid. pendant les Années 1863, 4, 5, and 6.

# CHAPTER II.

## THE CONDITIONS UNDER WHICH THE SOLDIER IS PLACED.

These conditions are extremely various, as the soldier serves in so many stations, but the chief points common to all can be passed in review.

The water and air supplies have been already sufficiently noticed (p. 2 and pp. 140 and 165), and the conditions now to be noticed under which the soldier is placed are barracks, huts, tents, and encampments; the food, clothing, and work.

## SECTION I.

### BARRACKS.

Barracks have been in our army, and in many armies of Europe still are, a fertile source of illness and loss of service. At all times the greatest care is necessary to counteract the injurious effects of compressing a number of persons into a restricted space. In the case of soldiers, the compression has been extreme; but the counteracting care has been wanting. It is not more than forty years since, in the West Indies, the men slept in hammocks touching each other, only 23 inches of lateral space being allowed for each man. At the same time, in England, the men slept in beds with two tiers, like the berths in a ship; and not unfrequently, each bed held four men. When it is added, that neither in the West Indies, nor in the home service, was such a thing as an opening for ventilation ever thought of, the state of the air can be imagined.

The means of removal of excreta were, even in our own days, of the rudest description, both at home and in many colonies; and from this cause alone there is no doubt that the great military nations have suffered a loss of men which, if expressed in money, would have been sufficient to rebuild and purify every barrack they possess.*

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* It is a most remarkable circumstance, that the two diseases which, in the French, Prussian, Hanoverian and Belgian armies, and probably in the Austrian, and, till lately, in our own army, caused the largest share of the mortality, were a destructive lung disease, termed phthisis in the returns, and typhoid fever.

The production of disorganising lung disease (though occurring in several other ways) is intimately connected with the constant breathing of an atmosphere vitiated by respiration; and typhoid fever is as closely related with bad drainage. Both diseases are therefore diseases of habitations, and show, in the case of the soldier (who is not subjected to other causes of phthisis such as inaction, constrained position, and inhalation of dust, &c.), that the air of his dwelling is foul. In hot climates the same rule holds good. Is it not a remarkable fact, that in the West Indies, those islands of paradise, where no cold inclement wind ever vexes the tender lungs, there was, twenty or thirty years ago, an extraordinary mortality from consumption, and from a continued fever, which in all probability was typhoid? Yet who can wonder, when we find, in the Windward and Leeward command, the very best barrack, in 1827, gave only this amount of accommodation: the men slept in hammocks touching each other; the average space allowed to each man measured only 23 inches in breadth; and the total cubic space per head, in this, the best barrack in a tropical climate, was only 250 cubic feet. The air was, of course, putrid in the highest degree.

So also in India, the best writer on the means of preserving the health of troops in India

## SUB-SECTION I.—BARRACKS ON HOME SERVICE.[*]

The imperfection of the English barracks was owing to two causes—first, a great disregard or ignorance of the laws of health; and, secondly, an indisposition on the part of Parliament to vote sums of money for a standing army. At the close of the last, and at the commencement of the present century, the Whig party especially opposed every grant which Mr Pitt brought forward for this purpose.[†] After the great war, the exhaustion of the nation prevented anything being done, and in spite of the representations of many military men, comparatively little change occurred till the Crimean War. In 1855, a committee,[‡] of which Lord Monck was chairman, was appointed by the War Office to consider this subject, and presented a most excellent Report on Barracks, the suggestions of which have been since gradually carried out. Immediately after this, a Barrack Improvement Commission[§] was organised, and in 1861 this Commission published a Blue Book, which not only contained plans and descriptions of the existing barracks and hospitals, but laid down rules for their construction, ventilation, and sewerage, for future guidance. It is difficult to speak too strongly of the excellence of this Report, and if its rules are attended to, there can be no doubt the British army will, as far as habitations are concerned, be lodged in healthier dwellings than almost any class of the community.[‖] I must refer to this report for a fuller account of the older barracks and hospitals than can be given here.[¶]

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(Dr Chevers), does not hesitate to assert that faulty barracks are, though not the only, yet a great cause of a mortality, which, in a term of years, has been at least fourfold more than at home. Phthisis and typhoid fever held a subordinate place (though it is not unlikely that their frequency is underrated); but other diseases appear, which are in part connected with faulty barrack arrangements, such as dysentery and cholera.

In India, as in England, no expense has of late years been spared; but yet the fact remains, that the very habitations erected for their shelter and comfort have proved to the soldiers a source of suffering and death.

[*] Army medical officers are referred to an admirable paper by Deputy-Inspector-General Dr Massy, on the Construction and Ventilation of Barracks and Hospitals (Army Med. Dep. Report, vol. vi. p. 229).

[†] On looking through the Annual Register, I find that Fox, as well as his followers, spoke strongly against the grant of sums of money for improving barracks. Their motives were good and their jealousy of a standing army justified by what had gone before, but the result has been most unfortunate for the soldier.

[‡] Report of the Official Committee on Barrack Accommodation for the Army, Blue Book 1855.

[§] Mr Sydney Herbert, Drs Sutherland and Burrell, and Captain Galton, were the first Barrack and Hospital Improvement Commissioners. Lord Herbert did not sign the first Report, as he became Minister of War. Dr Burrell retired. The remaining Commissioners (Dr Sutherland and Captain Galton) subsequently published the Report on the Mediterranean and other Barracks.

[‖] General Report of the Commission appointed for improving the sanitary condition of Barracks and Hospitals, 1861.

[¶] *The Hospital Regulations.*—The Director-General is to be consulted on the plans and site of any new barrack.

The Surgeon-General or Deputy Surgeon-General is ordered to see that all regulations for protecting health in barracks are carried out. He makes a monthly inspection, examining into ventilation, warming, lighting, latrines, closets, and all other points.

The regimental medical officer performs the same duties. He is also especially ordered to see that every soldier has a separate bed; that the beds are not placed at a less distance than 6 inches from the wall; that the beds are aired every morning for at least an hour; that the windows are opened in the morning as soon as possible, and kept open as far as weather and season will permit. The walls and ceilings are ordered to be limewashed twice a-year.

Each man is allowed 600 cubic feet of space, and the number of men located in each barrack room is to be painted on the door. This is a most important rule, which should be strictly enforced; if it is not so, it is to be stated in the Annual Report. No regulation is made as to superficial space, and it will vary with the height of the barrack room; from 56 to 60 square feet is the average.

### *Infantry Barracks.*

*Block Plan.*—Formerly a number of men, even a whole regiment, were aggregated in one large house, and this was often built in the form of a square (a plan originated by Vauban), the quarters for the officers forming one side, on account of the ease of surveillance. Many officers still prefer this form. But it is always objectionable to have an inclosed mass of air, and if it is adopted the angles should be left open, as recommended by Robert Jackson. The Barrack Improvement Commissioners have very justly recommended that there shall be division of the men among numerous detached buildings; and instead of the square, that the separate buildings shall be arranged in lines, each building being so placed as to impede as little as possible the movement of air on the other buildings, and the incidence of the sun's rays.

In arranging the lines, the axis of the buildings should be if possible north and south, so as to allow the sun's rays to fall on both sides. One building should in no case obstruct air and light from another, and each building must be at a sufficient distance from the adjoining house, and this distance should not be less than its own height, and if possible more.

*Parts of a Barrack.*—1. The barrack room, with non-commissioned officers' rooms screened off. 2. Quarters of the married privates—seven to each company. 3. Quarters of the staff-sergeants and sergeants' mess. 4. Quarters of the officers. 5. Kitchens. 6. Ablution rooms. 7. Latrines and urinals. 8. Orderly-room; guard-room. 9. Cells. 10. Tailors' shop and armoury; commissariat stores; canteen. 11. Reading-room (in many barracks); schools; magazine.

It is unnecessary to describe all these buildings.

The old barracks are of all conceivable forms and kinds of construction, for details of which I refer to the Commissioners' Report.

When new barracks are built, the plans of the Commission will be followed.

(*a*) *Barrack Rooms.*—The size and shape of the barrack room will decide the kind of buildings. The Barrack Committee of 1855 recommended that each room should accommodate twelve men, or one squad, as this is most comfortable for the men; but small rooms of this size are more difficult to arrange, and it is now considered best to put twenty-four, or one section, in each room.

The Barrack Improvement Commissioners' recommendations may be condensed as follows:—

The rooms are directed to be narrow, with only two rows of beds, and with opposite windows—one window to every two beds. As each man is allowed 600 cubic feet of space, and as it is strongly recommended that no room shall be lower than 12 feet, the size of a room for 24 men will be—length 60 feet, breadth 20 feet, height 12 feet. This size of room will give 14,400 cubic feet, or (600 × 24) enough for 24 men; but as the men's bodies and furniture take up space, an additional 2 feet has been allowed to the length in some of the new barracks. Assuming the length to be 62 feet, the superficial area for each man will be nearly 52 feet, a little more than 5 feet in the length and 10 in the width of the room. At one end of the room is the door, and a room for the sergeant of the section, which is about 14 feet

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The Queen's Regulations for the Army order the officer of the day to see to the ventilation and cleanliness of barracks.

Barracks are ordered to be washed once a-week, and no more water is to be used than necessary. On intermediate days the rooms are dry-scrubbed.

long, 10 wide, and 12 high. At the other end is a narrow passage leading to an ablution room, one basin being provided for 4 men, and a urinal.

Such is the present arrangement of a single barrack room, and it is difficult to conceive a better plan, unless it might be suggested that an open verandah, never to be made into a corridor, should be placed on the south or west side. It would be a lounging-place for the men. So also a cleaning-room for arms and accoutrements would be a very useful addition.

The room thus formed may constitute a single hut, but if space is a consideration, two such rooms are directed to be placed in a line, the lavatories being at the free ends. A house of this kind will accommodate half a company. The several houses are separated by an interval of not less than 25 feet. For the sake of economy, however, the houses will in future be frequently made two-storyed, so that one house will contain a company in four rooms, and ten will suffice for a regiment.

The three following plans of recently erected barracks show the arrangements which are adopted. 1*st*, When there is a single story, as at Colchester, and no staircase is required.

2*d*, When there are two storys, and a staircase must be introduced, as in the new cavalry barracks at York.

3*d*, When there are not only staircases, but the barracks must be extended in one long line, including many rooms, and when, therefore, the ablution rooms cannot be put at the ends of the rooms, but must be placed on the landings, as at Chelsea.

If 10 houses are thus formed, and arranged so as to insure for each the greatest amount of light and air, the following area will be occupied by these houses alone. Each house (with walls) would measure about 140 feet long and 22 broad, and the space between the houses may be taken at 64 feet, or twice the height of the house. The external houses would, of course, have clear spaces on both sides like the others. The area of occupied and unoccupied space would be very nearly 12 square yards to a man.

But this amount of compression, which would be injurious in a large city, will do no harm in these well-planned and ventilated barracks.

(*b*) *Day-rooms.*—The soldier lives and sleeps in his barrack room; it has long been a desideratum to introduce day-rooms,* but at present the expense is too heavy. Still it is very important

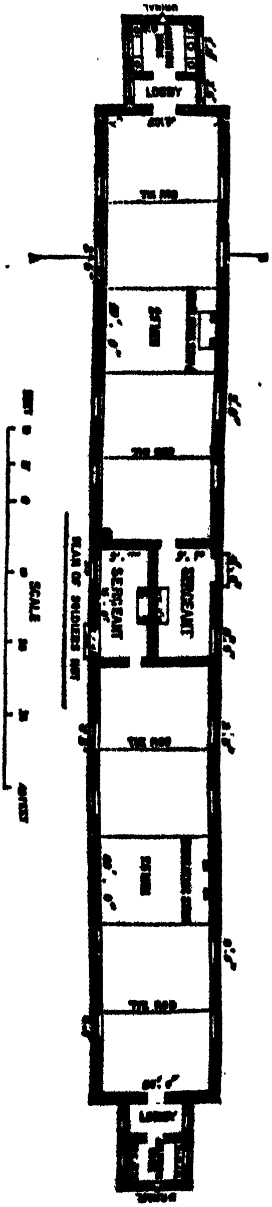

Fig. 104.—Colchester Camp Houses.

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* See Report of Committee (1855), p. iv. The objections to day-rooms are—1*st*, More labour

that the men should take their meals elsewhere than in their barrack room, and in some barracks a room is provided close to the kitchen. The addition

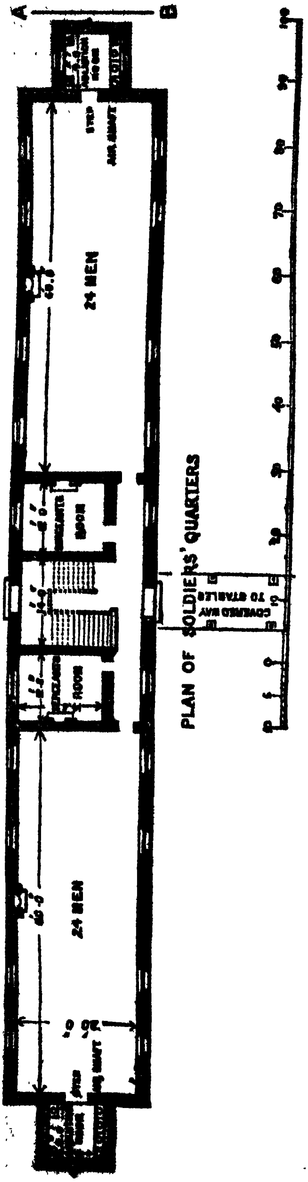

Fig. 105.—New Cavalry Barracks at York.

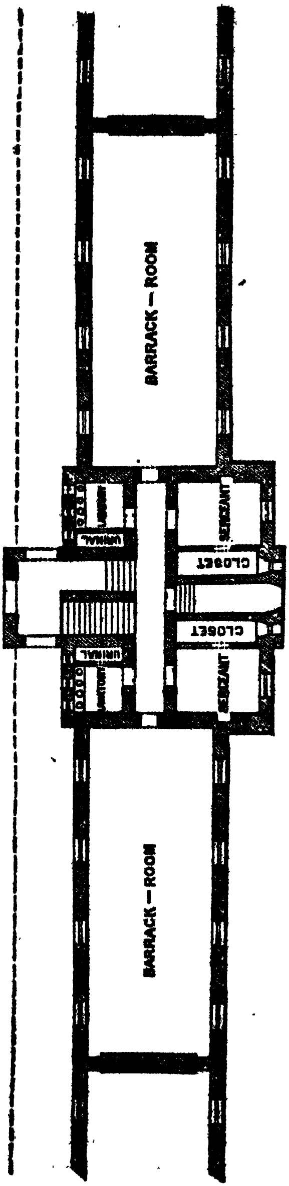

Fig. 106.—New Chelsea Barracks.

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to keep clean; 2d, Chance of men being debarred from their barrack room during day; 3d, Chance of day-room being appropriated on emergencies. The Committee, therefore, recommend only dining-rooms for the men, to be arranged near the kitchen, if possible.

of a few verandahs to the rooms would be less expensive; and if reading-rooms were provided, some of the purposes of day-rooms would be obtained.

(c) *Non-Commissioned Officers' Rooms.*—The Serjeant-major and Quartermaster-serjeant are entitled to two rooms and a kitchen; the Paymaster-sergeant, Hospital-sergeant, Schoolmaster-serjeant, and some others, are entitled to two rooms. The company serjeants have one room each. The rooms are about 14 feet by 12, and 10 high, and contain about 1680 cubic feet when empty. The amount of space is small, and as many of these non-commissioned officers are married, and as it is a matter of justice no less than of policy to make them as comfortable as possible, it is to be hoped that two rooms may be allowed to every married man, and three in the case of all the senior non-commissioned officers. The non-commissioned officers should be looked on in the light of the overlookers of a factory; they are even more essential to the good working of the army than the overlookers are in a mill; but no married overlookers would ever conceive the possibility of living in two rooms, in one of which cooking must be done.

(d) *Married Soldiers' Quarters.*—Seven privates in a company of 100 men are allowed to be married. Formerly they were placed in the men's barracks, a space being screened off, but now they are entitled to separate quarters, each family receiving one room 14 feet by 12, or 168 superficial and 1680 cubic space.

There is no doubt that this allowance of space will be increased in accordance with the general feeling of the time, which is strongly against the mixing up adults and children of all ages in the same room. The amount of space also is really much too small. Certainly two such rooms ought to be given to each married private.

*Warming of Barrack Rooms.*—The rooms are warmed by Galton grates in two ways—radiant heat from an open fire, and warm air, which is obtained from an air-chamber behind, and heated by the fire. The external air is led by a pipe to this chamber, and then ascending, enters the room by a louvre. The grates are of various sizes, according to the size of the room. Smallest—1 foot 3 inches of fire opening for rooms of 3600 cubic feet. Middle—1 foot 5 inches for rooms of 3600 and 9800 cubic feet. Largest—1 foot 9 inches up to 12,000 cubic feet. Large rooms have two grates. One grate is usually provided for twelve men.

The radiating power of the small barrack grate is aided by a well-arranged angle, and by a fire-clay back; as the fire is small, however, the radiating power is not great.

In the wards of Fort Pitt, with the largest size of grates, the mean rapidity of movement of warm air through the upper slits of the louvre, with a good fire, was found to be about 2½ feet per second, and the total cubic amount of warm air entering per hour through the whole louvre was (approximately) 4600 cubic feet per hour, with a mean temperature of 19° in excess of the external air-temperature. No unusual dryness of the air is produced by the admission of this quantity of warm air, the relative humidity of the air being about 70.

The movement of air through the hot-air louvres is not regular; open doors and windows, which increase the pressure of the air of the room on the louvre, will sometimes delay the movement, and, if the air-chamber is not very hot, will even reverse it and drive the air down, as the rapidity of movement in those hot-air chambers is never very great; but in cold weather, when the doors and windows are shut, the action is tolerably regular.

*Ventilation of Barrack Rooms.*—(See page 165).

*Ablution Rooms.*—Formerly the means for washing were of a very rude kind, but now in the new barracks regular basins with clean water and discharge dirty water-pipes are provided close to every room, in the proportion of one basin to four men. The basins are of slate or iron. In several cases basins on the floor have been provided for feet-washing, and in some instances there are also baths for each regiment. The Barrack Improvement Commissioners recommend one bath to every 100 men. It is understood to be the desire of the Government to provide plunge-baths wherever practicable, and this would not only aid cleanliness, but might be made the means of teaching the men swimming, as suggested by Mr M'Laren.

If water is scarce, the most economical kind of bath is a shower-bath, so arranged as to permit 80 to 100 men to have a bath at once.

Inspections for cleanliness are made in many regiments. They should be systematically carried on under the direction of good non-commissioned officers; but, if means are provided, soldiers will generally be cleanly.

*Kitchens.*—Great improvements have been made in cooking by the employment of better ovens and boilers, and especially by making use of steam, as in Warren's cooking stoves. The cost of fuel per head has been greatly reduced.

The opinion of the medical officer will seldom be asked on the question of construction, at any rate on home service. He may, however, be referred to on the question of consumption of fuel, and then he can take as the standard for an ordinary good apparatus ½ ℔ of fuel per man per diem.

More often, however, he will have to examine the cooking, to which reference is made under the different sections in the chapter on FOOD. The chief points to which attention should be paid, are the temperature, the rapidity of its application, and the ventilation of roasting ovens. Faulty cooking will generally be found to be owing to one or other of these conditions.

Formerly the regimental cooking establishment was badly arranged; men cooked by turns, and for short periods only. Now, cooks are regularly trained at Aldershot.

The other parts of a barrack are—officers' quarters; laundry (in some cases); workshops for tailor, shoemaker, and armourer; orderly-room; guard-room; cells; reading-room (in some cases); chapel and school, which are often in one; magazine; barrack-masters' and quarter-masters' stores for regimental purposes, bread, and meat.

*Guard-room.*—The guard-room for a regiment of 1000 strong has a size of about 24 feet by 18; two rooms open into it—one a lock-up for prisoners, the other a room where prisoners are placed who are not put in the lock-up. In many barracks, however, the lock-up is placed near the cells. The guard-room is ventilated like the other rooms, with Sheringham valves, shafts, &c. M'Kinnell's ventilator is well adapted for it. It should be fitted with a drying closet by the side of the fire, to dry the men's clothes when they come in wet off sentry.

*Cells.*—The cells are ranged on one or both sides of a corridor. They are 10 long, 6¾ feet wide, and 9 high (= 605 cubic feet), with one window, 2 feet 6 inches wide by 1 foot 3 inches high, placed at the top of the wall, and guarded by iron bars. A movable iron shutter is sometimes added for security, and to make the cell a dark one if needed. Fresh air is admitted through a grating opening from the corridor, which is warmed. The air enters below, or in some cases above; but the former arrangement is the best. A foul-air shaft runs from the top of the room. Two cells are provided for every 100 men. A medical officer inspects the cells every day.

*Latrines and Urinals.*—Formerly, urine tubs were brought into barrack rooms every night; and indeed this is still done in some barracks. The tubs are charred inside, and emptied every morning, and filled with water during the day. In all new barracks urinals are introduced; they are placed at the end of the passage beyond the ablution room. It is found by the men that this is inconvenient; the passage is often wet and cold. If the urinal is full of water it splashes; it might be well to put the overflow-pipe a little lower down. It has been recommended to put a small pipe and stopcock a few inches above the urinal, so that the men may cleanse themselves, and in this way possibly lessen the chances of syphilitic infection.

Cesspits are now discontinued in most barracks, and water latrines are used. The latrines are placed at some little distance from the rooms, and are usually connected with them by a covered way; in almost all barracks they are Jenning's or Macfarlane's patents. These are metal or earthenware troughs, which are one-third full of water. Twice a-day a trap-door is lifted, the latrine is flushed, and the soil flows into a sewer or tank at a distance. A hydrant is now frequently placed close to the latrine; an india-rubber pipe can be connected with it, and the seats and floor of the latrine are thoroughly washed in this way twice daily. Probably it would be difficult to suggest anything better than this, although soldiers can be taught to use water-closets like other people, and do not damage them. If water-closets are used, a plan suggested by Mr Williams, C.E., clerk of the works at Gravesend, seems a very good one. It is to have the water-closets at the top of a two-storeyed building, to the central part of which they form a small third storey. In this way the following advantages are secured:—vicinity to the men—under the same roof, yet with perfect ventilation; impossibility of effluvia passing down; proximity to the cistern; and a good fall. At present, however, it seems better to keep to the water latrines outside the barracks.

### *Cavalry Barracks.*

In many cases the men's rooms are placed over the stables, and there has been much discussion as to whether this arrangement is a good one. On the one hand, the men get more room, as the horses cannot be crowded, and they are near their horses. On the other hand, there is strong evidence that the effluvia from the stables pass into the men's rooms overhead;* and although I have been able to find no statistical proof that this has produced sickness among the men, we may safely *a priori* conclude that it is objectionable. The evidence of mews in London is not in point, as they are often close, ill-ventilated courts, independent of the stables in them. Besides, this evidence is as yet rather contradictory.

The question has, however, been solved by a "Report on the Ventilation of Cavalry Stables" (1863),† by the Barrack Improvement Commissioners, who have shown that the ventilation and lighting of stables can only be satisfactorily carried out in one-storeyed buildings, and who, therefore, recommend that the men's rooms shall not be placed over stables.

*Stables.*—The medical officer has no duties connected with stables, except to see that they are in no way injurious to the health of the men; but it may be well to give the suggestions lately made by the Barrack Improvement Commissioners.

In all the old stables, if it is not already done, ventilating shafts are to be carried up, air-bricks introduced, and more window space to be given.

Whenever stables are to be built in future, it is recommended that the building should be one-storyed; that the breadth should be 33 feet; the height of the side walls to the spring, 12; and of the roof, 8½ feet more. The breadth of each stall is to be 5½ feet, and there are only two rows of horses in each stable. Each horse is to have 100 superficial feet, and 1605 cubic feet; the ventilation is by the roof, and is formed by a louvre 16 inches wide carried from end to end, and giving 4 square feet of ventilating outlet for each horse. A course of air-bricks is carried round at the eaves, giving 1 square foot of inlet to each horse; an air-brick is introduced about 6 inches from the ground in every two stalls. There is a swing window for every stall, and spaces are left below the doors. In this way, and by attention to surface drainage and roof lighting, it is anticipated that stables will become perfectly healthy. Some experiments were made some years ago by Dr de Chaumont on the air of some artillery stables at Hilsea. In one stable, with 32 ventilators, and with 655 cubic feet per horse, the $CO_2$ was 1·053 volumes per 1000; in another, with 1000 cubic feet per horse, and with 420 air-bricks, 25 windows, and a ridge opening, it was ·573 volumes per 1000. The last experiment shows great purity of the air.

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* See especially the evidence of Mr Wilkinson, Principal Veterinary Surgeon to the Army; Report of Barrack Committee (1855), p. 136, question 2262; also the Report on the Ventilation of Cavalry Stables (1863).

† Report of Barrack and Hospital Improvement Commission, signed by Sir Richard Airey, Captain Galton, Dr Sutherland, Dr Logan, and Captain Belfield.

### *Reports on Barracks.*

The Regulations order the form in which reports on barracks shall be sent in. The arrangements should be strictly followed; it comprehends site, construction, external ventilation, internal ventilation, basements, and administration. It is then certain that no point will be overlooked; and, if nothing can be made out after going thoroughly through all the headings, it may be concluded that the cause of any prevailing sickness must be sought elsewhere. The site and basement should be especially looked at; every cellar should be entered, and the drainage thoroughly investigated. Little can be learned by merely walking through a barrack room, which is nearly sure to look clean, and may present nothing obviously wrong. With respect to ventilation, the statements of soldiers can seldom be trusted; they are accustomed to vitiated air, and do not perceive its odour. The proper time to examine the air of a room is about 12 to 3 A.M., and the medical officer should, accordingly, visit barrack rooms between midnight and 3 A.M. every now and then. The cisterns should be regularly inspected.

The walls and floors of the rooms should be carefully looked to. Walls are porous, and often become impregnated with organic matter. If there is any suspicion of this, they should be scraped and then well washed with quicklime. The medical officer should see that the lime is really caustic; chalk and water does little good. Collections of dirt form under the floors sometimes, and a board might be taken up to see if this is the case.

### Sub-Section II.—Barracks in Forts and Citadels.

In fortified places it is, of course, often impossible to follow the examples of good barracks just given. Citadels may have little ground space; buildings must be compressed, guarded from shot, made with thick and bomb-proof walls, with few openings. Buildings are sometimes underground. Drainage is often difficult, or impossible; and if to all these causes of contamination of air we add a deficiency of water, which is common enough, it will not surprise us that the sickness and mortality in forts, in even healthy localities, are greater than should be the case. Both at Malta and Gibraltar there has for years been too large a mortality from typhoid fever, and from the destructive lung diseases, which appear in the returns as phthisis. The special difficulties of casemates are as follows: dampness, which is very common in all casemates, so that the moisture often stands in drops on the walls; a low temperature; a want of ventilation; and a want of light.

How these difficulties are to be met is one of the most difficult problems the military engineer has before him. How, without weakening his defences, he is to get light and air into the buildings, and an efficient sewerage, would test the ingenuity of a Brunel. It is possible that the best plan would be by the employment of thick movable iron doors and shutters. In time of peace these might be open; in time of war easily replaced. But, in addition, means of ventilation must be provided when such defences close the usual openings; tubes must be carried up, and, if necessarily winding, an enlarged area might, perhaps, compensate for this.

It must be said, also, that it is quite certain that in our fortified places many of the arrangements are much worse than they need be, and that the sanitary rules deducible from home experience should be applied in every case when the defensive properties are not interfered with.

## SUB-SECTION III.—BARRACKS IN HOT CLIMATES.

The older barracks in both the East and West Indies were often merely copies of the English barrack square. In some cases, also, the exigencies of defence led to a cramped and irregular plan, and owing to the little attention which was paid either to the health or comfort of the soldier, overcrowding and deficient ventilation were as common in the tropics as at home. For several years there has been a gradual improvement, and in India especially vast and extensive palaces have been reared in many stations, which testify at any rate to the anxiety of the Government to house their soldiers properly.*

It will be desirable to refer here chiefly to the Indian barracks, but the same principles apply to all hot countries.

The Indian Sanitary Commission have lately recommended that each man in barracks shall have 100 superficial feet, and 1500 cubic feet. The Government of India recommended in 1864 that there should be 90 superficial feet in the plains, and 77 in the hills, which, with a width of 24 and 22 feet, and height of 20 and 18 feet, would give 1800 cubic feet in the plains and 1408 in the hills. Mr Webb,† who has paid great attention to the subject of over-crowding in Indian barracks, and who believes that it is the grand cause of insalubrity in India, has adduced good reasons for thinking that this amount is not nearly sufficient. It is suggested, indeed, that 3000 cubic feet of space is not too much.

I shall not refer to the old barracks, but to the later and the present patterns.

In 1857 and 1858 the Bengal Government ordered standard plans to be prepared, and some barracks have been built in accordance with them. A description and figures will be found in the former editions of this work. In 1863 the Governor-General of India in Council ordered a renewed inquiry into the matter, and Colonel Crommelin submitted altered designs for barracks, which were subsequently submitted to the Bengal, Madras, and Bombay Governments, and to the Army Sanitary Committee at home. The plan of these new barracks is essentially that proposed by the Indian Sanitary Commission; while the preparation of the detailed design is left to the local officers, certain general principles are strictly laid down, and standard plans suitable for different localities are furnished for different guidance. The number of men to be placed under one roof is fixed at 40 or 50 (half company barracks), except under exceptional circumstances; the number of men in one room is to be 16 to 20, and not to exceed 24; the barracks are to be two-storeyed in the plains, and one or two storeyed in the hills, both floors being used for dormitories; single verandahs of 10 or 12 feet wide surround these rooms. There are to be only two rows of beds in the dormitories; the beds are to be 9 inches from the wall, and only two beds are to be in the wall space between two contiguous doors (or windows); in the plains each bed is to have 7½ feet of running wall space, in the hills 7. The general arrangements of the building are based on the suggestions of the Royal Indian Sanitary Commission. At each end of the dormitory are closets and night urinals; and what appears to be the best plan places these at the extreme end of the verandah, leaving a space between them and the dormitory.

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* Some of these great barracks, as at Allahabad, have not given satisfaction, and have been found as hot or even hotter than the old barracks. But this appears to have been from not attending to the rule, never to let the sun's rays fall on a main wall, but to shadow the wall by a verandah. The double roof also has apparently not been sufficiently double, *i.e.*, the openings above and below, to allow the air to circulate, have not been large enough; ventilators have also not been put to the verandahs, so that the heated mass of air cannot ascend. Nothing tends to cause greater heat than stagnancy of the air, as may be seen by the ease with which water may be boiled in a close vessel by the rays of the sun, even in England. The objection to the palaces which have been built in India since the mutiny, is not, I conceive, so much to the principle of the barracks, but to some faults in construction, and especially to their localities, viz., in the plains instead of in the hills in many cases.

† Remarks on the Health of European Soldiers in India. By H. Webb. Bombay, [illegible] p. [illegible]

The lower story in the plains was intended to be used as a day-room, but it appears that this has not been comfortable for the men, and both floors are now used as dormitories.

The married people's quarters are to be grouped in small one-storied blocks, each block holding the married people of a company or troop. Two rooms (16 feet × 14 feet and 14 feet × 10 feet) are provided for each family; verandahs, 12 and 10 feet wide, are provided.

In all these arrangements it will be perceived that the essential principles of the home barracks are preserved; long, thin, narrow lines of buildings, with thorough cross ventilation, with the sleeping-rooms raised well off the ground, would certainly appear to be as good an arrangement as could be devised. A few more remarks on some of the points have to be made.

1. *Size of Houses.*—If there are no strong military reasons to the contrary, it seems certain that it is even more important in India than in England to spread the men over the widest available area, and not to place more than fifty men in a single block, and twenty-five men in a single room; and, therefore, the proposed plan is most desirable. There has been an objection raised, that small detached houses in the hot plains of India, not having any large space in shadow, get everywhere heated by the sun's rays, and become very hot. The objection is theoretical; it is the immense blocks of masonry used in the construction of large buildings which are to be avoided as much as possible, since, when once heated, they take hours to cool.

2. *Arrangement of Houses.*—Broadside on to the prevalent wind, and disposition *en échelon*, as now adopted in India, is obviously the proper plan. The only exception will be when there are marsh or gully winds to be avoided, and then the houses should be placed end on to the deleterious wind; and no windows should open on that side. But it is seldom such a site would be selected or kept.

If a barrack is built on a slope, and the ground is terraced, the Army Sanitary Committee have recommended that the barrack should be placed end on to the side of the hill, and not nearer the slope than 20 to 30 feet. But terracing should be avoided as much as possible.

3. *Breadth of Houses.*—As in England, it is important to have only two

rows of beds in each house, and to keep the houses under 30 feet in width, so as to permit effective perflation. A single verandah is as good as a double one in keeping off the direct rays of the sun from the walls of the house, and two verandahs (one inner and one outer) add to the breadth to be ventilated. The width of the verandahs must be 10 to 12 feet; and on the southern and western sides wooden jalousies may have to be placed so as to occupy 3 or 4 feet at the upper part of the verandah.

Verandahs should be ventilated by openings at the highest part, so as to have a free movement of air through them ; this is very important. If there are two storys, the roof of the upper verandah should be double.

*Materials of Building.*—On this point there is little choice, for the risk of fire renders the use of wood undesirable for walls and roofs. And yet, apart from this risk, loosely joined wood, or frames of bamboo, have the great advantage of allowing air to pass through the walls. Brick or stone has therefore to be used. In India, sun-dried brick (*kutcha*), covered with cement, or faced with burnt brick, is often used ; and the remains of Babylon or Nineveh show how imperishable a material this is if properly protected. It is said to be a cooler material than burnt brick (*pucka*), but it absorbs a great deal of moisture.

Iron barracks were sent out from England during the mutiny, but were said to be hot, and were not liked ; but iron frames have been usefully employed, the intervals being filled up with unburnt bricks. There is, however, a very general feeling against unburnt brick, on account of the moisture it absorbs and retains. The concrete walls now coming into so much use in England would be particularly adapted for India ; they are cheap, and are dry.

*Construction of the Building.*—The three points to be aimed at are—avoiding the malaria and dampness of the ground, should there be any risk of this ; insuring coolness ; providing ventilation.

(*a*) *Employment of Open Arches for the Basement.*—The extraordinary diminution in the risk of malaria by elevating the building only a few feet above the ground, and allowing a free current of air under the house, is illustrated in various parts of the world : along the banks of the lower Danube, in the plains of Burmah and Siam, &c. But another great benefit is obtained : dryness and freedom from pent-up, stagnant, and often septic masses of air are insured, so that, even when the soil is not distinctly malarious, buildings should be raised. In a malarious country the height of the ground-floor above the ground should be 8 or 10 feet ; in non-malarious districts 3 or 4 feet are sufficient, but it should always be high enough to allow cleaning.

If high enough, these open spaces afford excellent spaces for exercise during the heat of sun.

(*b*) *Walls.*—Very thick brick walls do not add to coolness (Chevers), but being thoroughly heated during the day, give out heat all night. The direct rays of the sun should not be allowed to fall on any part of the main wall. This will be found one of the most important rules for insuring coolness. Double main walls, with a wide space between, and free openings above and below, so as to admit a constant movement of air between, is the coolest plan known. Considering the excellent ventilation which goes on in bamboo and wooden houses, it may be a question whether, in the warm parts of India, the walls might not be made as far as possible permeable ; at any rate, above the heads of the men. Whitening the outside walls reflects the heat, but is dazzling to the eyes ; almost as good reflection, and much less dazzling, is obtained by using a slight amount of yellow or light blue colour in the cement or lime-wash.

(*c*) *Floors.*—The materials at present used are flagstones (in Bengal), slates (in some barracks in the Punjab), greenstone (in some Madras barracks), tiles, bricks placed on end and covered with concrete, pounded brick and lime beaten into a solid concrete and plastered with lime, broken nodulated limestone or kunkur (in places where the masses of kunkur are found, as in Bengal), asphalt, pitch, and sand, wood (Chevers). Of these various materials, the asphalt gets soft and is objectionable; the cements and kunkur wear into holes, produce dust, and have been supposed to cause ophthalmia (Chevers); wood is liable to attacks of white ants, &c.

On the whole, it would seem that good wood (if there be a space below the barracks) with brick supports is the best, and after this tiles.

(*d*) *Roofs.*—Double roofs are now usually employed, and are made slanting, and not terraced. The terraced roofs, if made single (*i.e.*, with battens on the joists covered with kunkur), conduct heat too freely; but if made double, with a good current of air, there is an advantage in giving a promenade to the men, and also, at some seasons of the year, the roof may be most advantageously used as a sleeping-place.

The sloping roofs are better adapted for ventilation. The coolest roof is made of thatch, covered with tiles; it would be cooler still if the thatch were outside; but thatch is dangerous on account of fire, and harbours vermin and insects. If there is a good space between the two roofs (2 feet), and if there are sufficient openings to permit a good current of air, perhaps two tile roofs would be as cool as any.

(*e*) *Doors and Windows.*—These are now always made very numerous, and opposite each other, so as to permit perfect perflation. The official "Suggestions" order one window for every two beds. Five doors are recommended for each room of twenty-five men; and Norman Chevers gives a good rule: A light placed in the centre at night should be seen on all sides. Upper as well as lower windows—a clerestory, in fact—are useful; the lower windows should then open to the ground. In most of the stations in northern India the windows must be glazed.

The committee appointed to carry out the suggestions of the Indian Sanitary Commission have recommended that each window should consist of two parts —the upper portion, about 2 feet in depth, being hinged on its lower edge to fall inwards, so as to direct the currents of air towards the ceiling of the room.

### *Ventilation of Tropical and Subtropical Barracks.*

If barracks are not made too broad, and are properly placed, the same principles of ventilation may be applied to them as to barracks at home. The perflation of the wind should be obtained as freely as possible. The numerous doors and windows, however, render it unnecessary to provide special inlets; outlets should, as at home, be at the top of the room, either along the ridge, or if of shafts, they should be carried up some distance; if they are made of masonry, and painted black, the sun's rays will cause a good up-current. The area of the shafts is ordered ("Suggestions," p. 22) to be 1 square inch to every 15 or 20 cubic feet, with louvres above and inverted louvres below. In the lower rooms these shafts are to be built in the walls; in the upper rooms to be in the centre.

In many parts of India, however, at particular times of the year, the air is both hot and stagnant; in such stations artificial ventilation must be employed, and the forcing in of air offers greater advantages than the method by aspiration. The wheel of Desaguliers was introduced into India many years ago by Dr Rankine, and, under the name of "Thermantidote," is frequently used in private houses and hospitals. Wheels may be used of a larger kind, and driven by horses and bullocks, or steam or water power. The great advantage is that the air can be taken through a tunnel, and cooled either by the cooler earth or by evaporation (see *Cooling of Air*).

An Arnott's pump, made as large as a man can easily work, will be found to be cheaper, and as good as the thermantidote.

The common punkah is a ventilator, as it displaces masses of air; the waves pass far beyond the building, and are replaced by fresh air waves entering in. An improved punkah, worked by horse or bullock, and supplied with water for evaporation, was devised by the late Mr Moorsom of the 52d Regiment; it is described and figured in the report of the Indian Sanitary Commission, and would seem likely to be a very useful modification of the common punkah.

Ventilation in most parts of India must be combined with plans for cooling, and often for moistening the air.

*Cooling of Air.*—When the air is dry, *i.e.*, when the relative humidity is low, there is no difficulty in cooling the air to almost any extent. If the air be moving, this is still easier. The evaporation of water is the great cooling agency. A drop of water in evaporating, absorbs as much heat as would raise 967 equal drops 1° Fahr., or in other words, the evaporation of a gallon of water absorbs as much heat from the air as would raise 4½ gallons of water from zero to the boiling point. As the specific heat of an equal weight of air is ¼ that of water, it follows that the evaporation of 1 gallon or 10 ℔ of water will cool (10 × 4 × 967) 38,680 ℔ of air, or 477,637 cubic feet of air 1° Fahr., or, to put it in another way, the evaporation of 1 gallon of water will reduce 26,216 cubic feet of air from 80° to 60° Fahr. If thoroughly utilised, 1½ gallon per head would be the allowance for 12 hours, but as the full work is never got out of any material, this quantity ought in practice to be doubled. In India the temperature of a hot dry wind is often reduced 15° to 20° by blowing through a wet kuskus tattie; but merely sprinkling water on the floors will have a perceptible effect on the temperature.

When the air is stagnant cooling is less easy. In India it is often attempted, in a still atmosphere, to insure coolness by creating currents of air either by the simple punkah or by thermantidotes; these act by increasing evaporation from the body, and they certainly do away with the oppressiveness of a still atmosphere. But evaporation of water must be also employed, as in Captain Moorsom's punkah just referred to, or in some other way.

In the case of a thermantidote, or Arnott pump, thin wet cloths suspended in a short discharge-tube, or ice suspended in it, or a bottle containing a freezing mixture, and with a wet surface, will answer equally well.

When water is abundant other contrivances may be employed. A stream of water issues from a small orifice with a high velocity, and impinging on a round iron plate about an inch or two from the orifice, is beautifully pulverised. Or the beautiful sheet-water fountains used to wash air for ventilation might be employed. In the old Roman, and some Italian houses coolness was obtained by a fountain in the central court; and where it can be done, the more common employment of fountains in the houses in the hot parts of India may be suggested.

Cooling is then easy when the air is dry, or is not moister than 70 per cent. of saturation; but when the air is very moist, and almost saturated, as is often the case, for example, in Lower Scinde, and is at the same time still, evaporation is very slow. What can be done? Of course the air must be set in motion by mechanical means. But how is it to be cooled? Two plans suggest themselves—taking the air through a deep tunnel, and the employment of ice.

The tunnel plan was tried, I believe, some years ago at Agra, and was not well thought of. But everything depends on the mode of making the tunnel. It must be deep enough to get into a cold stratum of earth.[*]

The Chinese, in the north of China, suspend lumps of ice in their rooms during the summer; but this seems a wasteful plan. Ice in tunnels would have a much greater effect. If the ice cannot be obtained, freezing mixtures might possibly be used, if the expense is not a bar.

*Ablution Rooms.*—In India, every private house, and almost every room in a house, belonging to a European, has its bath-room. And not only the luxury, but the benefit is so great, that bath-rooms should be considered essential to every barrack. For the usual purposes of ablution the plan now used on home service is the best; but it should be supplemented by shower-baths. In order that these shall be efficiently given, the old plan of carrying water by hand must be given up; shower-baths for a regiment could never be provided in this way; water in large quantity must be laid on in pipes, and cisterns at the top of every barrack should feed the ablution rooms, and supply water for the urinals. At least from 12 to 18 gallons daily should be allowed per head for shower-baths alone, and, if possible, more than this, as general baths should be also provided. So essential must baths be considered for health, that a large supply of water should be considered a necessary condition in the choice of site. The disposal of the water after use is a question for the engineer; but it must not be permitted to soak into the ground near the barracks; it might seem superfluous to notice this, if the custom of allowing the ablution water to run under the houses did not prevail at some stations.

*Urinals.*—Urine tubs are still used in many of the barracks in India, but their use should be discontinued as soon as possible. Evaporation is rapid, and decomposition soon sets in. Several army surgeons have pointed out that the atmosphere is greatly contaminated in this way, and some have considered that affections of the eyes are produced by the ammoniacal fumes. Earthenware or slate urinals should be used, with water running through them; and if there are no drains to carry off the urine, a zinc pipe may be laid inside the building, and open into a tub below, which should be emptied daily.

The War-office Committee, in their "Suggestions" (p. 24), recommended Mr Jenning's urinal, which consists of a basin, valve, and syphon-trap, supplied with water. It is cleaned and filled by raising the handle. As already noticed in the Home Barracks, the suggestion of a small water-tap above, to allow the means of ablution, seems an excellent one.

### SUB-SECTION IV.—WOODEN HUTS.

Of late years the use of wooden huts, both in peace and war, has greatly extended in several of the European armies. In peace, their first cost is small, and they are very healthy. In war, they afford the means of housing an army expeditiously, and are better adapted for winter quarters than tents.

The healthiness of wooden huts doubtless depends on the free ventilation; when single-cased, the wind blows through them; and even when double-cased, there is generally good roof and gable ventilation.

Numerous patterns of huts have been used in our own and other armies, from small houses holding six men to the large houses designed by Mr Brunel for Renkioi Hospital, and which were 25 feet high in the centre, 12 feet at the eaves, and held 50 men. In the Crimea the most common sizes were for 12, 18, and 24 men. Sir Garnet Wolseley thinks the most useful size is 32 feet long, 16 wide, 6 feet to eaves, and 16 to ridge, to hold 28 men; two huts are put end to end, with one chimney between them. If protection has to be obtained against wind, make a wall a foot away.

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[*] The recent investigations into the composition of the ground air, give additional reasons for objecting to the tunnel plan, unless the utmost care were taken to prevent the ground air being delivered into the dwellings (see page 327).

In arranging lines of huts, as much external ventilation and sunlight must be secured as possible for every hut. According to circumstances, the arrangements in lines, or *en échelon*, &c., must be adopted.

In time of peace huts are sure to be put up well; to be properly underpinned; on a drained site, and well warmed.

### *War Huts.*

In the putting up of huts in the time of war, when everything is done more roughly, the following points should be attended to:—

Do not excavate ground, if possible; and never pile earth against the sides.*

(*a*) *Floor.*—Whenever practicable, underpin the joists, so as to get a current of air under the floor. Arrange for the drainage underneath, so that water may not lie, but may be carried by a surface drain at once to an outside drain. If the floor is entirely of wood, have it screwed, and not nailed down,† so that the boards may be taken up, and the space below cleaned. If the sides are of planks, and the centre of earth, pave the centre with small stones, if they can be got, so that it may be swept. If this cannot be done, remove a little of the surface earth every now and then, and put clean sand or gravel down.

(*b*) *Sides.*—If the sides are double, leave out a plank at the bottom of the outside, and at the top of the inner lining. If the sides are single, make oblique openings for ventilation above the men's heads, with wooden flaps falling inwards, and capable of being pulled more or less up, and inclosing the opening. Place a plank obliquely along the bottom at the outside, to throw the drip from the roof outwards, so that the water may not sink under the houses. Whitewash both inside and outside of the planks.

(*c*) *Roof.*—Arrange for ridge ventilation. If felt is used, let the strips run along the sides, and not over the ridge, and beginning at the bottom, so that each successive strip may imbricate over the one below it; use no nails, but place thin strips of board across the strips from the ridge downwards, to hold the felt down. Tarred calico is as good as felt.

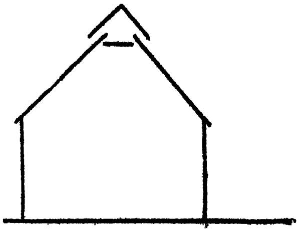

Fig. 107.

*Warming.*—In cold countries, if stoves are provided, place them at one end, and let the chimney run horizontally along above the tie-beams, to the other end, and open at the gable; in this way, the heat is economised: or put a casing of wood round the stove, except in front, and allow fresh air to pass between the stove and casing. If no stoves are provided, and a fire-place is made with stone, it should be put at one end, and a wooden trough running out at the gable be used as a chimney. If a good broad slab of stone can be obtained for a hearth-stone, dig a trench under the boards and lead the air from outside under the hearth-stone, and provide an opening at the other side of the stone. In this way the entering air is warmed.

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* While it is desirable to have the walls as clear from accumulations outside as possible, it it must be remembered that this rule, like others, has its exception. Thus, in a very cold country, like Canada, a sufficient degree of warmth could not be obtained in a wooden hut without piling snow up against the sides.

† If possible the screws should be of copper, not iron; if of iron each screw ought to be dipped in oil before being put in: this greatly increases the ease with which they can be withdrawn, and also saves the wood to some degree.

Trenches should be carried round huts as in the case of tents.

Fig. 108 shows a plan much used by the Germans in 1870–71 for temporary sheds; the crossing of the rafters permits thorough roof ventilation, and the raising from the ground where practicable is very important.

### *Causes of Unhealthiness of Wooden Huts.*

1. *Dampness from Ground, Earth against Wall, &c.*—Drain well. Cut away ground from outside; have good trenches round, with a good fall.

2. *Substances collecting under Floors.*—Look well to this as a common cause of unhealthiness.

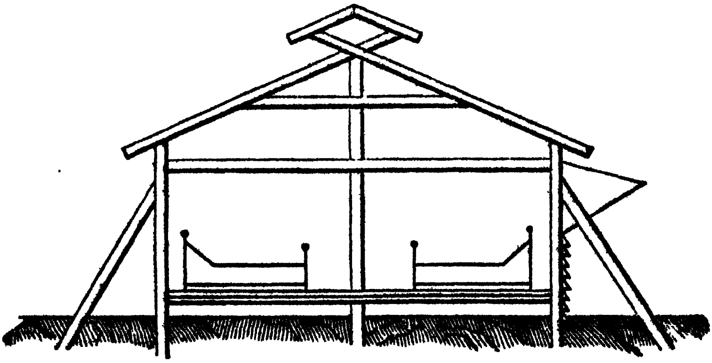

Fig. 108.—Plan of German Shed.

3. *Earth round Huts saturated with Refuse, Urine, &c.*—Every now and then clear away the surface earth, and replace it with clean dry earth.

4. *Ventilation* bad from too few openings.

5. *Cold.*—Issue extra clothes, if additional fuel cannot be obtained. See that the greatest effect is obtained from the fuel; but do not, if it can possibly be helped, close the ventilators.

## SUB-SECTION V.—TENTS AND CAMPS.

### TENTS.

A good tent should be light, so that it may be easily transported, readily and firmly pitched, and easily taken down. It should completely protect from weather, be well ventilated, and durable.

It is perfectly easy to devise a tent with some of these characteristics, but not to combine them all.

The tents used in our army are as follows:—

### *Home Service.*

*The Bell-Tent.*—A round tent with sides straight to 1 or 2 feet high, and then slanting to a central pole. Diameter of base, 14 feet; height, 10 feet; area of base, 154 square feet; cubic space, 513 feet; weight, when dry,* about 65 to 70 lb. The canvas of the new pattern is made of cotton or linen. The ropes extend about 1½ foot all around. It holds from twelve to sixteen men; and in war time, even eighteen have been in one tent. The men lie with their feet towards the pole, their heads to the canvas. With eighteen men, the men's shoulders touch. Formerly, there was no attempt at ventilation; but afterwards a few holes were made in the canvas near the pole. Ventilation, however, was most imperfect.* Dr Fyffe (formerly of the Army Medical School), who carefully examined this point, found the holes so small, that the movement of air was almost imperceptible. There is little ventilation through the canvas, and none at all when it is wet with dew. The new circular tent is somewhat improved as regards ventilation.

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* Complete wetting of a tent adds from 30 to 40 per cent. to the weight.

*The Hospital Marquee.*—An improved hospital marquee was issued in 1866. It is in principle the same as the old marquee, but with improved ventilation. This tent is two-poled, with double canvas. It is made of a lower, almost quadrangular part, and an upper part, sloping from the top of the straight portion to the ridge.

A new pattern measured in 1872 was 28 feet long, 14 feet in width in the quadrangular part, 5 feet high to the top of the straight part, and 12 feet high from ground to top of ridge; the ground space was 353·4 feet, and the cubic space 2766·6 feet. This is rather smaller than the old pattern.

It is intended for sick, and can accommodate ten men well; eighteen is the regulation, and twenty-four men have been put in it; but this crowds it extremely. There are ventilators, and a large flap at the top can also be opened for ventilation, and the fly can be raised. Its weight (including the valise) is about 500 lb. A waterproof sheet is now supplied, to put on the ground, and this weighs 145 lb.

It is a good tent when care is taken with ventilation; but there should be a way of raising one whole side, so as to expose every part of the tent; and if the height of the upright part were 6 feet, it would be more convenient.

*Circular Tent.*—A double circular tent, weighing about 100 lbs., has been approved of for hospital purposes, into which four sick or wounded men would be placed. This forms part of the new field equipment.

*Shelter Tent.*—There is no official shelter tent for the English army on home service, but one was formerly issued for service at the Cape. Each man carried a canvas sheet, made up of a quadrangular (5 feet 9 inches × 5 feet 3 inches) and of a triangular piece (2 feet 8 inches height of triangle × 5 feet 3 inches base). Buttons and button-holes were sewn along three sides, and a stick (4 feet long, and divided in the middle) and three tent pegs and rope also were provided. Two or four of these sheets could be put together, the triangles forming the end flaps. A very roomy and comfortable shelter tent, 4 feet in height, was formed, which would, with a little crowding, accommodate six men, so that two sheets could go on the ground. The objection to this tent was its weight, viz., 6 lb 14 ounces per man. If a thinner material could be obtained, and if the size could be a little lessened in all directions, it would be a very good tent. I have attempted to arrange a cape and waterproof sheet in such a way as to form a tent when suspended on rifles.† A plan for making a shelter tent with blankets is given in the "Instructions for Encampments," 1877, p. 19, paragraph 14.

*Officers' Tents.*—Marquees are allowed, one for each field-officer; each captain, and every two subalterns, have one circular tent. The officers' marquee weighs 176 lbs.

### *On Indian Service.*

The tents for Europeans are marquees, with two poles and ridge, double fly. Length, 21 feet; breadth, 15; height to inner fly, 10 feet 3 inches;

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† Army Med. Depart. Report for 1870; 1872, p. 262.

and outer fly, 11 feet 9 inches. Twenty-five infantry are accommodated with 85 cubic feet per man; or twenty cavalry with saddles, with 100 cubic feet.

The tents for natives have a single fly. Length, 22 feet; breadth, 12; height of pole, 10 feet; to accommodate twenty cavalry, or twenty-five infantry.

*French Tents.*—In the French army, two chief kinds of soldiers' tents are used.

1. The *tente d'abri*, or shelter-tent of hempen canvas, is intended for three or four men. Each man carries one-third or one-fourth of the tent, and a stick; the weight of the two being 3 ℔. The canvas he carries serves him for a covering while marching; or he can form it into a bag, into which he can creep. Each sheet is 5 feet 8 inches long, and 5 feet 3 inches broad; the stick is 4 feet 4 inches long, and 1½ inch in diameter. When the tent is pitched, the three men can creep inside, and have as much space and as good ventilation as the English soldier in the bell-tent. This sort of tent has the great advantage of giving protection during the march, and immediate cover when the march is over. The number of baggage animals for the army is also greatly lessened.

Some of the French *tentes d'abri* are intended for four or six men; the length is 6½ feet, the height, 3¼; it is carried by three or four men. The total weight of the tent is from 6½ to 8¾ ℔.*

2. *Tente de Troupe, or Tente Taconnet.*—This is a two-poled tent, with a connecting ridge-pole. It is 19½ feet long, by 13 or 14 wide, and 10 high; the ground area is 243·5 square feet. It is intended for sixteen men. There are two openings in the centre, which can be held out by poles, each 5 feet in length, or closed at pleasure. Between the poles, at the height of 6 feet, there is a perforated wooden plank, on which articles are placed, or from which they hang. The total weight is 143·5 ℔ avoir. This tent is considered cumbersome and unstable, and is now being abandoned.

3. Two conical tents are also used, like the English bell-tent; one (*tente conique*) a cone, and the other having an upright wall 16 inches high, and then being conical above (*tente conique á muraille*). This last tent is ventilated at the top; a galvanised iron ring, 12 inches in diameter, receives the canvas, which is sewed round it. An opening is thus left of 113 square inches, which can be closed by a wooden top which rests on the top of the pole, and is buckled to the ring. Each tent holds twenty men. The *tente conique* is the one now chiefly used. Small tents called *tentes de marche* are now issued to officers, who formerly provided their own of various forms.

*Prussian Tent.*—This is a conical tent, with a single pole, like the bell-tent of the English army; it is nearly 16 feet in diameter, the pole 12 feet high; it holds fifteen men, and weighs 91 ℔ avoir. The floor space is 12 square feet and the cubic space 70 cubic feet per head.

*Prussian Hospital Tent.*—The ground-floor of the tent is a rectangle 62 feet long and 24 broad; the tent is 16 feet high; there are 6 or 8 poles; the area is 1488 square feet. It is divided into three parts: a central, 52 feet long and 24 broad (= 1248 square feet), for the sick, and two rooms, each 5 feet long and 24 broad, for attendants, utensils, &c. Some of the tents are made with hollow iron poles, and there is a good hood for ventilation. Each tent could contain 20 to 22 beds, but only 12 patients are placed in it. It stands on an area of 80 feet by 40. Since 1862 the Prussians have treated many of the worst cases under such tents during the summer. The same practice has been adopted in the Austrian army for the last 16 years.

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* Larger shelters may be made by combining the portions carried by several men. Morache complains of the general introduction of the *tente d'abri* in the French army, as charging the soldier permanently with extra weight to provide for him only an illusory shelter.

† From Heyfelder's Camp of Krasnoe-Selo, 1863.

*Russian Tent.*—The infantry tent is quadrangular, 14 feet square and 7 feet high to the slope; there is a centre pole and four corner poles; it is intended for fourteen men, but only twelve are usually placed in it. Round the tent is a bench 1½ foot broad, and covered with straw mattresses and sheets (in the summer camps) for sleeping. A wooden rack round the centre pillar receives the rifles. The canvas can be partly or entirely lifted up. The officers' tents have double canvas.

*Northern American Tents.*—At the commencement of the civil war the Sibley tent was much used. It is conical, 18 feet in diameter, and 13 feet high, with an opening for ventilation, and gives 1102 cubic feet; often twenty or twenty-two men were held by one tent. Bell and wedge-shaped tents were also used; the latter was 6 feet 10 inches long, 8 feet 4 inches broad, and 6 feet 10 inches high, with a cubic space of 194 feet. It held six men.

These tents, however, did not answer; the ventilation was most imperfect, and in the summer of 1862 ponchos and shelter-tents were issued, which in the army of the Potomac superseded the old tents.* The poncho is a piece of oil-cloth with a slit in the centre, through which the head is put; two ponchos can form a shelter-tent. The army of the Potomac spent the winter in improvised huts of logs or mud, with the shelter-tent for the roof.

The larger tents are, however, still used for stationary commands, and for hospital purposes.

*Other Plans.*—A very great number of different kinds of tents are employed by different nations, and many plans have been proposed of late years.† Of these Edgington's square military tent, and Turner's and Rhodes' tents, are the best. The first is a single poled pyramidal tent, with a second pole to sustain the entrance flap; it is 13 feet square, and will hold sixteen men. There are ventilating holes through the canvas at the top, protected by canvas. It weighs 90 lb.

Turner's tents are conical and oblong; the pole is hollow iron, and is supported in a tripod, below which a stove can be placed, to which the pole serves as a chimney. Instead of ropes, galvanised wire and iron pegs are used, and wire ropes running from the pole to the circumference are used to sustain hammocks, and so raise the men from the ground. A tent for eighteen men weighs 300 lb. Turner's hospital tent is 60 feet long, 29 wide, and 18 high, and weighs 896 lb.‡ A great advantage of these and similar tents is that a stove can be easily used, and there is pretty good ventilation through the hollow pole. The raising of men off the ground is also a great advantage.

Major Rhodes' tent is a curvilinear octagon, which is made up by a frame of stout ash or bamboo ribs, which are stuck into the ground, passing through a double-twisted rope near the ground, and bent into the centre, where they meet in a wooden head fitted with iron sockets, to receive the ends of the ribs. The framework is not unlike an open umbrella. The rope through which the ribs pass is well pegged to the ground, and there are also outside storm ropes, so that, both from the shape of the tent and its ties, no storm can blow it over. There is a good top ventilation through an opening protected by a leathern cap, and the canvas covering which contains the tent (when packed) can be divided into two parts, and buttoned inside the bottom of the tent, so as to prevent air from blowing in under the canvas.

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* Woodward, Outlines of the Chief Camp Diseases of the United States Army, 1863, p. 48.

† A very good description will be found in Major Rhodes' Tent Life and Encamping, 1859.

‡ Rhodes, p. 178.

A small tent (guard tent), capable of holding four or five men, is also used.

The hospital tent is made of two of these tents connected by a portion of tent made of ribs which run to a ridge pole. It is 30 feet long, 15 feet wide, and 10 feet high, but can be made of any length. The field tent weighs 100lb; the hospital tent, 395 lb. Both these seem excellent tents; they give much more ground area, cubic space, and standing room, than any form of cone tent, and are more convenient, as there are no poles.

### *General Conclusions.*

The history of all wars in the temperate zone proves that men cannot war without protection from weather.[*] Both theory and experience show that the best arrangement for a soldier is that he should carry a portion of a shelter-tent, which may at once serve him for a cloak on the march, and a cover at night, if he is obliged to lie out without pitching his tent, and which, joined to two or three other similar pieces, may make a tent to hold three or four. For camps of position, where troops are kept for months, and where there is less trouble about transport, larger tents can be used, and then either a tent like that of Major Rhodes', or a two or four poled tent like the Prussian, appears to be the best.

The French system, now adopted by the Americans, is in reality a very old one. The Macedonians used small tents which held two men,[†] and Rhodes figures a little shelter-tent of the same form as the French, and holding apparently five men, which was in use in the British army in 1750.

At various times in late wars the English army have extemporised tents of this description, by suspending blankets over their firelocks. But it would be much better to have a good shelter-tent, which would make the men independent of their bell-tents, on emergency, and thus greatly lessen the baggage of the army, as well as protect the men.

An army could then encamp and house itself as fast as it could take up its ground, and so short is the time necessary for pitching the tent that even in heavy rain the men would not get wet. The men lie much more comfortably than in the bell-tent,[‡] and there is scarcely a possibility of its being blown down.

## CAMPS.

Several regulations have been issued by the Quartermaster-General's Department,[§] and the "Queen's Regulations" (pocket edition, section 16), contain several orders which will be noticed hereafter. The Barrack Improvement Commissioners also, in their Report (1861, p. 168), lay down certain rules which must be attended to.

Encampments are divided into two kinds—those of position, which are intended to stand for some time, and incidental camps. The camps are arranged in the same way in peace and war, as a means of training the men; but, of course, in peace the war arrangements need not be adhered to.

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[*] The Franco-German war of 1870–71, does not negative the rule that shelter must be given in some way; the Germans in their camps hutted themselves, and in their marches found shelter in houses in the greater number of cases.

[†] Rhodes' Tent Life, p. 13.

[‡] In some of the last China expeditions waterproof sheets were issued, of which the men made tents as well as cloaks. I was told by a private soldier who carried one of these, that nothing more comfortable was ever issued to the men. His sheet was the last thing that a man would part with.

[§] Regulations and Instructions for Encampments, "Horse Guards," 1877. A great deal of very important information is given in this little book.

In the Regulations and Instructions issued in 1877 by the Quartermaster-General's Department, the following rules are laid down:—

1. That the means of passing freely through the camp should be maintained.

2. That the tents, bivouacs, or huts should be disposed with a view to the greatest amount of order, cleanness, ventilation, and salubrity.

3. That the camp be as compactly arranged as possible, consistently with the above considerations.

Troops are ordered to be encamped in such a manner that they can be rapidly formed in a good position for action. This does not involve the necessity of encamping on the very position itself.* Although purely strategical or tactical considerations are of the first importance before an enemy, yet sanitary advantages must always be allowed great weight, and will, in most cases, govern the choice of ground if military reasons permit. Cavalry and infantry camps are directed to be formed with such intervals between their troops or companies as circumstances may require, or the general commanding may direct. Open column is usually the most extended order used,—but the camp may be so compressed as to give only 8 square yards per head.†

In front of the camp is the battalion parade, the quarter-guard being in front of all. Behind the men's tents are the kitchens, and behind these the tents of the officers; then come the wagons, horses, drivers, and batmen; next the ashpit and latrines, and on the boundary line the rearguard. In fixed camps the latrines and kitchens may be pitched elsewhere, if found advisable.

The distances between different corps are, as a rule, to be 30 paces.

Cavalry are encamped in the same way, in columns of troops or squadrons; 4 feet of space is allowed to each horse, which is picketed.

Artillery encamp with the guns in front, the wagons in two lines behind, and the horses and men on the flanks, the men being outside, the officers' tents being in rear. A battery of artillery, with 192 of all ranks, and 154 horses, occupies a space of 175½ yards by 133 in open order, and 85 by 71½ in close order. Other arrangements are given in the Regulations.‡

On considering these arrangements, it is evident that the compression of the men is considerable. As in war it is not always easy to give space, the importance, even in a military point of view, of thoroughly ventilating the tents is obvious.

*Compressed Camps.*—Occasionally the tents have been placed much closer together. It is to be presumed that no military officer who regards the comfort or health of his men will ever do so without an imperative military necessity. Yet it has been occasionally done, and tents have been placed almost as closely as they could be, even when ground was available, and no enemy was in front. Under these circumstances, an explanation of the reasons for not crowding the men together will undoubtedly satisfy the officer in command that he is sacrificing comfort, convenience, and efficiency, to a false notion of order and neatness.

In the Crimea, many officers dug out the interior of their tents, leaving a small pillar of earth to support the pole; a ledge of about 9 inches in width was also left all round the outside to serve as a shelf; a great deal of comfort and shelter was thus given in cold winds, but it would be well to go to as little depth as possible unless the soil is dry.

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* Regulations and Instructions for Encampments, p. 1, section 6.

† Measurements in infantry camps are usually made in paces: 6 paces=5 yards; other camps are measured in yards.

‡ For numerous plates of camps, tents, kitchens, &c., the reader is referred to the Instructions and Regulations for Encampments, price 6d.—which ought to be in the hands of every officer.

### *Points to be attended to in the Erection and Conservancy of Camps.*

Dig a trench round each tent, 4 inches deep, and the width of the spade, and carry it into a good surface drain running in front of the tents, with a proper fall. Place the tent on the ground and do not excavate, or to a slight extent; in a camp of position, the tents can sometimes be raised on a wall constructed of stones, or even earth, if this can be plastered over. Whenever possible, let the floor of the tent be boarded, the boards being loose, and able to be removed. If there are materials, make a framework elevated a few inches from the ground to carry the boards. If boards cannot be obtained, canvas or waterproof sheets should be used; whatever is used, take care that nothing collects below, and move both boards and canvas frequently to see to this, and scrape the earth if it is at all impregnated. If straw is used for bedding, get the men to use it carefully; to place pegs of wood or stones, and make ropes of straw running from peg to peg, so that each man may keep his own place neat; or to make mats of straw of a triangular shape, and 3 or 4 inches thick. Take care that the straw is kept dry, and never allow the men to use green foliage, or any damp substance. Have the sides of the tent thoroughly raised during the day, and even at night, to leeward. Whenever practicable (twice a-week if it can be done), the tents should be struck, the boards taken up, the surface well cleaned, the worst part of the straw removed and burnt.

In a camp of position dry paths should be constructed between the different roads; latrines should be dug in rear of the stables, and not too near the kitchen, and *en échelon* with the camp; for a standing camp each latrine should be a trench 20 to 50 feet long, according to the size of the camp, 10 deep and 2 wide at the top, and 3 at the bottom. The earth thrown out should be arranged on three sides. It should be screened by branches of trees, and 9 inches of earth should be thrown in every day.* When 4 feet from the surface, it should be filled in and another dug, the earth of the old one being raised like a mound to mark the spot. Close to it an urinal should be constructed, of a sloping channel paved as well as can be, and leading into the latrines, or of a tub which can be emptied into it, and, as far as possible, men should be prevented from passing the urine round their tents. In camps for a few days a trench 12 paces long, 2 feet deep, 2 feet wide at top and 1 foot at bottom, is sufficient.

A corps of scavengers should be immediately organised to clean away all surface filth, and to attend to the latrines and urinals. All refuse must be completely removed; it is often a good plan to burn it. Both in peace and war, encamping ground should be often changed, and an old camp should never be re-occupied.

In addition to tents, the men may be taught, if possible, to house themselves. Huts of wattle should be run up, or wooden sheds of some kind. In war, men soon learn to house themselves. Luscombe gives the following account of the huts in the Peninsula:—

"A cork tree or evergreen oak with wide-spreading branches was chosen, a lower branch was nearly cut through, so as to allow the extreme points to drop to the ground. Other branches were then cut from adjoining trees and fixed in a circle in the ground, through the branch, on which their upper branches rested. Smaller branches were then interwoven to thicken the walls, and the inside was lined with the broom-plant, which was thatched in. The door of the hut was put due east, so that the sun might pass over it before it reached the horizon."

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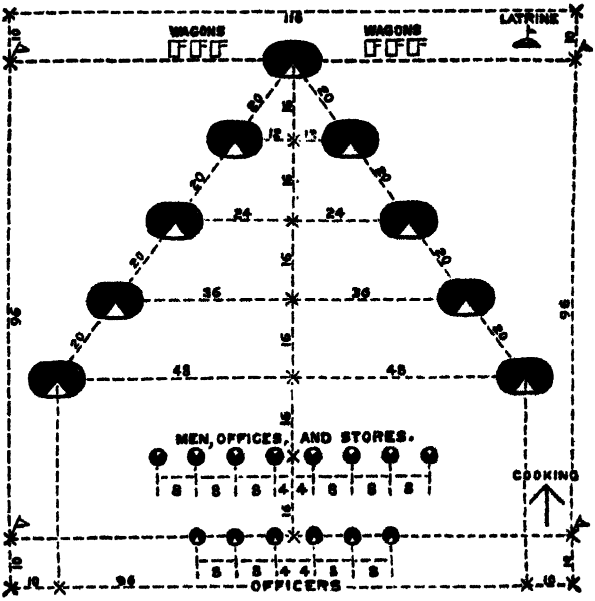
* The Regulations direct only 2 or 3 inches of earth.

This hut was very cool during the day, but *very cold* at night, and thus "very prejudicial to health."

Sir Garnet Wolseley states that many English officers and the Sardinians generally, in the Crimea, made comfortable huts in the following way:—A space was dug out 2½ feet deep, and the size of the hut; those made to contain 6 Sardinian soldiers were 14 feet 3 inches long, and 7 feet 1 inch wide in the clear. Gables were then built of mud or stone, or made of boards or wattle and daub; the gables were 2 feet wider than the excavation, so as to form a shelf all round; a door was in one and a window in the other. The fireplace was made of brick or mud, or simply cut out of the face of the earth in one of the side walls, a flue being bored in a slanting direction, so as to come out clear of the roof, and being provided with a chimney 2 feet in height. The pitch of these roofs should be at an angle of 45°.*

Hospital Encampment of 9 Marquees and 14 Tents.



Measurements are in paces to centre poles of marquees.
Total depth, 116 paces. Total length of front, 116 paces.

Fig. 109.

Underground huts are sometimes used in camps; they are, however, dangerous; they are often damp, and are difficult of ventilation. In cold, dry countries, however, they are warm, and the Turks have constantly used them in campaigns in winter on the Danube. They have, however, frequently suffered from typhus. If used, there should be two openings besides the chimney, so as to allow a current of air; and a spot should be chosen where it is least likely water will gravitate. But underground huts are always to be discouraged if any substitutes can be found. Sometimes the side of a hill is cut into, and the open top covered with boards and earth. This is as bad as an underground hut.

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* Drawings of various kinds of huts and bivouacs are given in the Regulations, *op. cit.*

### *Hospital Encampment.*

When marquees are available, and a good piece of ground can be selected, the best plan is to arrange the marquees in the form of a triangle. The figure (109) shows the plan proposed by Surgeon-Major Moffitt, who has paid great attention to this point. In the plan 9 marquees are arranged, but 3, 5, 7, or a larger number than 9, may be equally well placed in the same order. There is good exposure to air, and convenience in administration.

## SECTION II.

## THE FOOD OF THE SOLDIER—ARMY REGULATIONS.

The Army Medical Regulations place the food both of the healthy and sick soldier under the control of the medical officer. He is directed to ascertain that the rations of the healthy men are good, and that the cooking is properly performed; the amount of food for the sick is expressly fixed. On taking the field, the principal medical officer is ordered to advise on the subject of rations, as well as on all other points affecting the health of the troops. It will thus be seen that a great responsibility has been thrown on the Medical Department, and that its members will be called upon to give opinions on the quantity of all kinds of food supplied to soldiers; on the composition of diet; on the quality and adulteration of the different articles; and on their cooking and preparation.

In the case of soldiers and sailors, definite quantities or rations of food must be given. It is, of course, impossible to fix a ration which shall suit all persons. Some will eat more, some less, but certainly every scale of rations should err on the side of excess rather than defect.

The following are the rations of the chief European armies :—

### *English Soldier on Home Service.*

The English soldier receives from Government 1 lb of bread, and ¾ lb of meat, and buys additional bread, vegetables, milk, and groceries. The following table shows his usual food :—

*Nutritive Value in Ounces (avoir.) and Tenths of Ounces.*

| Articles. | Quantity taken daily in oz. and tenths of oz. | Water. | Nitrogenous Substances. | Fat. | Carbohydrates. | Salts. |
|---|---|---|---|---|---|---|
| Meat, . . | 12 oz. (of which ¼th is bone.) | 7·20 | 1·44 | 0·80 | ... | ·154 |
| Bread, . . | 24 oz. | 9·60 | 1·92 | 0·36 | 11·81 | ·312 |
| Potatoes, . . | 16 ,, | 11·84 | 0·24 | 0·02 | 3·75 | ·020 |
| Other vegetables, | 8 ,, | 7·28 | 0·16 | 0·04 | 0·46 | ·056 |
| Milk, . . | 3·25 ,, | 2·92 | 0·10 | 0·08 | 0·13 | ·016 |
| Sugar, . . | 1·33 ,, | 0·04 | ... | ... | 1·28 | ·006 |
| Salt, . . . | 0·25 ,, | ... | ... | ... | ... | ·250 |
| Coffee, . . | 0·33 ,, | ... | ... | ... | ... | ... |
| Tea, . . . | 0·16 ,, | ... | ... | ... | ... | ... |
| Total Quantity, | 65·32 oz. | 38·88 | 3·86 | 1·30 | 17·43 | ·808 |

Calculating this by the tables given at page 196 it would give—

| | | Grains. |
|---|---|---|
| Nitrogen, | | 266 |
| Carbon in albuminates, | 899·38 | 4718 |
| Carbon in fats, | 449·28 | |
| Carbon in starches, | 3369·37 | |

The quantity of nitrogen is considerably below that of the standard diet, while the amount of carbon is nearly correct, only this is given chiefly in the form of carbo-hydrates, and not as fat. The diet would be improved by the addition of more meat or of cheese, and by the addition of butter or of oil. So also, while fresh succulent vegetables are sufficient, the use of peas and beans, as in the French army, would be very desirable.*

Using Dr Frankland's table, and taking the bread ⅕th crust and ⅘ths crumbs, and the "other vegetables" as cabbage, the total force obtainable in the body from the soldier's daily diet appears to be equal to lifting 3848·5 tons one foot. The amount for the internal and external mechanical work of the body being taken at 700 tons lifted a foot, there remains 3148 tons for the equivalent amount of heat and all the other processes.

The accessory foods are rather deficient in the soldier's food, and vinegar especially should be used. Robert Jackson very justly insisted on the importance of vinegar as a digestive agent and flavourer, as well, no doubt, as an anti-scorbutic. He remarks on the great use of vinegar made by the Romans, and possibly the comparative exemption which they had from scurvy was due to this.

The diet of the soldier on foreign stations is stated under the several headings when it differs materially from that of home service, and the alterations in the diet which should be made under circumstances of great exertions are given in the proper chapter.

In the time of Edward VI. the English soldier's rations during war were—meat 2 ℔, bread 1 ℔, wine 1 pint (Froude).

No scale of diet is laid down for war, and probably it would be fixed at the time, and in view of the possible character of the campaign. The war scale should be very liberal, and every article ought to be issued by the Supply Department. It would be probably a good plan to have the supply under two headings, the "usual" and the "extra" articles, the latter being intended for special occasions, such as forced marches, rapid movements far from the base of supplies, &c. The usual ration ought not to contain less than 375 to 400 grains of nitrogen. The following is suggested as a liberal and varied war ration, which could be easily supplied under ordinary cases:—Bread, 1¼ ℔; fresh meat (without bone), 1 ℔; peas or beans, 3 ounces; potatoes or green vegetables, ½ ℔; cheese, 2 ounces; sugar, 2 ounces; salt, ½ ounce;† pepper, 1/36 ounce; ground coffee, 1 ounce; tea, ½ ounce; red wine, 10 ounces, or beer 20 ounces. No spirit ration to be given, except under order from the generals of divisions. The nutritive value of this diet is about 380 grains of nitrogen and 5000 of carbon.[*]

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* That the food of the English soldier is deficient, especially for the younger men, is known also from evidence. The late Director-General (Sir James B. Gibson) strongly urged on the authorities the desirability of increasing the ration of meat, and in the report on the recruiting of the army the same point was brought forward. I have made inquiries from soldiers, and find the recruits and young soldiers could eat much more; though the old soldiers, many of whom have been long accustomed to take spirits, and who have injured their digestive powers by so doing, take less food. I have no doubt, however, that, taking the army through, the ration, especially of meat, is not enough. For further remarks, see The Soldier's Ration, by F. de Chaumont, Sanitary Record, Feb. 5, 1876.

† It may be suggested that chloride and phosphate of potassium, and perhaps a little citrate of iron, might be added to the common salt.

The "extra" articles would be kept in readiness by the Supply Department for occasional issue, viz., salt meat, Australian meat, Chicago meat, dried meat (such as Hassall's or M'Call's, or the best market article of the kind), Liebig's extract of meat, pea and beef sausages, biscuits, flour, meat biscuits, rice, lime juice, preserved vegetables, brandy or rum, and vinegar.

This plan supposes that the "usual" scale of diet would be issued to the troops, and the "extra" articles under certain conditions, and under order of the general of the division.

Bread (which should be well-baked) should be issued as long as possible;[†] and if biscuit is issued for more than a week, flour or rice should be added to it. When salt meat is issued for several days in succession, vinegar should be given with it. If no vegetables can be obtained, lime juice should be early had recourse to.

The usual alcoholic ration of the troops should be beer or wine, instead of spirits (see page 302). As all the continental armies issue wine rations in war, there can be no difficulty on the score of transport; and even with beer, though twice as bulky as wine, it is believed that it could be in most cases supplied.

But the issue of red wine instead of spirits is strongly urged.

For rapid expeditions, when transport has to be reduced to the minimum, the use of concentrated and cooked foods is all important. The men can carry enough for seven or eight days, and are then independent of all base of supply.

Pea and flour sausages, meat biscuits, and dried meat, are the best to use; and the issue of cheese and bacon fat, if it can be obtained with these, gives a diet which is fairly nutritious and not disagreeable. The following would be the weight of food which would last a man for a week, and render him independent of the Commissariat during that time:—Biscuit, 2 ℔; pea or flour meat sausage, 4 ℔; dried meat, 2 ℔; sugar, ¾ ℔; tea, ¼ ℔; cheese, 1 ℔;—total, 10 ℔. That is to say, a weight of 10 ℔, which would be lessening day by day, would, if properly used by the men, carry them through a week's labour, and although, of course, a meagre diet, would yet enable them to do their work.

The extract of meat, as an extra ration, is intended for another purpose. It has a great restorative power, and should be kept for special cases, such as the following:—

1. It is expected the army, after a rapid march, will meet the enemy, and that there will be no time for preparing food. A small quantity of Liebig's extract, merely mixed with 3 or 4 ounces of red wine, will restore strength in a wonderful way; no cooking is required, and ten minutes time will supply a whole regiment.

2. The force meets heavy weather, and every man is drenched. The issue of Liebig's extract, made into hot soup, and with wine added, will have a very great effect in preventing bad consequences.

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[*] For further remarks see "Military Hygieue," a lecture by F. de Chaumont, Journal of the United Service Institution, 1870.

[†] Steam baking ovens have been used in the Autumn Manœuvres, and have been found very good. Field ovens were also built by iron hoops fixed in the ground. Sir G. Wolseley gives the following plan:—Take a barrel (with iron hoops, if possible), knock out the head, lay it on its side, after scraping a bed for it; cover it with a coating of 6 or 8 inches of thick mud, except at the open end; pile up sand or earth to a thickness of 6 inches over the mud; arrange a flue at the end distant from the open part, through the mud and earth, of 3 inches diameter, to increase the draught when the fire is burning. Form an even surface of well-kneaded mud at the bottom of the barrel; light a fire in the barrel, and keep it alight until all the wood is burnt; there will then be a good oven of clay, supported by the iron hoops. When heated for baking, the mouth is closed with boards, or a piece of iron or tin. These ovens were used in the Red River Expedition, and answered admirably.

3. A forced march has to be made in a very short time, and no fires can be lighted for cooking. Liebig's extract in small tins should be distributed to the men, who should spread it on their biscuits.

4. After action it is invaluable for wounded men, and can be carried about the field and given to the men who cannot be brought into the hospital.

It would be convenient to have the extract carried in cases holding small quantities, so that one pot may be issued to ten or twenty men.

The strength and use will require to be explained.

In war the supply of food is often difficult, but as an army "fights on its belly," the importance of food at critical movements cannot be overrated. The uncertainty of the time of supply, and the difficulty of cooking, often cause the men to be without food for so many hours as to greatly exhaust them; and *some actions* have been *lost*, *others* have remained without *good* result, from this cause. This can only be avoided by regimental transport of condensed and ready-cooked food, which may be used on such emergencies, and given in addition to the usual rations issued by the Supply Departments. The colonel of a regiment would then always be sure that he had the means of keeping up the strength and vigour of his men. The Germans are now trying a plan of cooking, which is intended to obviate one difficulty on the march.* A Viennese engineer (Herr Beuerle) has altered Papin's digester in such a way as to make it a convenient cooking utensil, and it is now in use in the Austrian ambulances. It is a doubly conic iron pot covered with a lid, and capable of standing the pressure of five atmospheres; the lid is fastened by screws, and a layer of felt or india-rubber is between it and the rim of the pot, so as to exclude air; in the lid is a ventilating opening, weighted to 2·5℔ (Austrian = 3·1 ℔ English), so that it opens when the pressure exceeds one atmosphere. The meat, salt, vegetables, &c., are put into this digester, and it is filled up with water till about 3 fingers' breadth from the top. The amount of water is 1 pint (English) to 1 ℔ of meat (English). This makes so strong a soup that it has to be diluted. The pot with the lid screwed down is put on the fire (three iron supports from which the pot hangs, like a gipsy's kettle, are provided for the field), and as soon as steam is developed, which is known by opening the ventilator a little, the fire is moderated. In an hour and a half the soup is ready. Pots to cook from eight to twenty-five rations are made, and special arrangements are made for cooking potatoes, &c. The plan is, in fact, in principle similar to Warren's compressed steam boilers, now used in the army, but is simpler.

One advantage in active service of this plan is, that if the troops are surprised, and have to move off their ground before the soup is ready, the pot is simply thrown into the waggon, and at the end of the march the soup is usually found to be ready.†

### RATIONS OF THE FRENCH SOLDIER.‡

#### *In time of Peace.*

Under the new regulations of 1873, the Government furnishes the meat for the soldiers' rations at about 35 per cent. under market price. This has proved a great advantage for the soldier. The State also furnishes bread (pain de maintien) and fuel; the white bread (pain de soupe), as well as other articles, are bought from the funds of the *ordinaire*, or common fund of the company, battery, or squadron. To this the soldier pays 43 centimes a-day, out of 48 that he receives, except in Paris, when his contribution is 51, out of a total of 58. The remaining 5 or 7 centimes he receives in cash.

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* Der Beuerle'sche Dampfkochtopf.—Deutsche Militairarztliche Zeitsch. 1872, heft v. p. 215.

† In the Crimea, Soyer introduced various portable cooking stoves, but probably the compressed steam cooking will supersede all others. Soyer also gave several receipts for field cooking, which were found to be very useful. A number of these receipts were printed in 1872 at the Royal Artillery Institution at Woolwich. In case of a war, it would be useful to print some receipts of the same kind, adapted to the particular sort of cooking stove then in use.

‡ Code des Officiers de Santé, par Didiot, 1863, pp. 481, *et seq.* Alterations have been made in the scale of diet since 1874; the new scale is given in the text.

*Infantry of the Line.**

| | Grammes. | Ounces avoir. |
|---|---|---|
| Munition bread, . . . . | 750 | 26·5 |
| White bread for soup, . . . | 250 | 8·8 |
| Meat (*uncooked*), . . . . | 300† | 10·6 |
| Vegetables, (green), . . . . | 100 | 3·5 |
| " (dried), . . . . | 30 | 1·1 |
| Salt, . . . . . . . | 15 | 0·5 |
| Pepper, . . . . . . . | 2 | 0·07<br>= 31 grains. |
| Total . . . . . | | 51·70 |

If biscuit is issued, 550 grammes (or 19·4 ounces) are given in place of bread. If salt beef is used, 250 grammes (8·8 ounces) are issued, or 200 (7 oz.) of salt pork. Haricot beans form the chief part of the dried vegetables.

Analysed by the table for calculating diets, and deducting 20 per cent. from the meat for bone, the water-free food of the French infantry soldier is, in ounces and tenths—

| | Water. | Albuminates. | Fats. | Starches. |
|---|---|---|---|---|
| Bread, . . . . . . . . | 14·15 | 2·820 | 0·530 | 17·25 |
| Meat, . . . . . . . . | 6·30 | 1·260 | 0·705 | ... |
| Vegetables (taken as cabbage), . . | 3·19 | 0·007 | 0·017 | 0·21 |
| Vegetables dried (as peas) . . . | 0·16 | 0·242 | 0·022 | 0·56 |
| Total, . . . . . . | 23·80 | 4·329 | 1·274 | 18·04 |

In Algiers the ration of bread is also 750 grammes, or 26·5 ounces, and 8·8 ounces for soup, or biscuit 643 grammes. The meat is the same; 60 grammes of rice and 15 of salt are issued, and on the march, sugar, coffee, and ¼ litre of wine.

*In time of War* (*Morache*).

| | Total. | Water. | Albuminates. | Fats. | Starches. |
|---|---|---|---|---|---|
| Meat (without bone), . . | 8·40 | 6·3 | 1·26 | 0·70 | ... |
| Bread, . . . . . | 35·30 | 14·1 | 2·82 | 0·53 | 17·25 |
| Or Biscuit, . . . . | (26·50) | ... | ... | .. | ... |
| Dried Vegetables, . . . | 2·12 | ... | 0·50 | ... | 1·50 |
| Total, . . . . . | 45·82 | 20·4 | 4·58 | 1·23 | 18·75 |
| Salt, . . . . . . | ½ oz. | Total water-free food, 24·56 oz. | | | |
| Sugar, . . . . . | $\frac{7}{10}$ " | | | | |
| Coffee, . . . . . | $\frac{6}{10}$ " | | | | |

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* As given by Morache, Traité d'Hygiène Militaire, 1874.

† 240 without bone—8·4 ounces.

The sugar and coffee are sometimes replaced by 25 centilitres (9 ounces) of wine, or 6½ centilitres (2·2 ounces) of brandy.

## GERMAN SOLDIER.*

The soldier receives his pay every ten days—*i.e.*, three times a-month ; it amounts to three thalers (or 9 shillings English) per month,† or 3 silbergroschen (= 3½ pence nearly) a day. Out of this he has to defray the cost of a warm dinner ("menage") at the rate of 1¼ silbergroschen (= 1¼ penny) ; and he also receives a mess contribution, varying according to the market prices of food.‡

*Bread.*—In garrison, the daily ration of bread is 1 ℔ 12 loth§ = 24·67 English ounces, and is issued in loaves for four days, weighing 98·68 English ounces. On the march, in some fortresses, and to prisoners sentenced to hard labour, the larger bread ration of 1 ℔ 26 loth = 32·93 English ounces, daily is issued. On the march, the soldier, when quartered in private houses, gets his mess contribution deducted, but has the right to be supplied by his landlord with 32·93 (English) oz. rye bread, 8·82 (English) oz. meat, vegetables, and salt, the latter in sufficient quantity for two meals (dinner and supper). Soldiers in cantonments or bivouacs are provided with food from the stores, and their mess contribution is, of course, deducted.

The rations in time of peace are divided into the smaller and the larger victualling rations.

| | Smaller Ration, in ounces avoir. | Larger Ration for Marches, &c., as supplied from the Military Stores, in ounces avoir. |
|---|---|---|
| Bread, . . . . . . | 26·50 | 26·50 |
| Meat (raw), . . . . | 6·00 | 8·82 |
| Rice, . . . . . . | 3·20 | 4·22 |
| Or unhusked Barley (Groats), . | 4·21 | 5·28 |
| Or Peas or Beans, . . . | 8·22 | 10·60 |
| Or Potatoes.‖ . . . | 53·08 | 70·5 |
| Salt, . . . . . . | 0·87 | 0·87 |
| Coffee, . . . . . . | 0·468 | 0·468 |

Troops, when travelling on railway or on steamers, receive an additional pay of 2½ silbergroschen (= 3 pence) per man for refreshments. Should the travelling last longer than 16 hours, the additional pay is doubled.

*In time of War.*—The supply of rations for the Germans during the Franco-German war was thus conducted :—

1. During the marches in Germany the men were billeted, and money was paid for their food.
2. Supplies were drawn from the magazines.
3. Supplies were obtained by requisition when the troops entered France.

This last plan was a bad one, as was especially shown in the march to Sedan,

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[*] For this information I have to thank my friend Dr Roth, of the Prussian Army.

[†] Lance-corporals and privates which have engaged themselves to serve a longer term of years receive an additional pay—1 thaler (3 shillings) per month.

[‡] In the new currency—1 thaler = 3 marks ; 1 mark = 100 pfennings ; 1 silbergroschen = 10 pfennings.

[§] The Prussian weights are now assimilated to the French ; the Prussian pound is = ½ kilogramme or 500 grammes ; the loth = 16·66 grammes or ·5879 oz. avoir.

[‖] 25 per cent. is lost in boiling and peeling ; besides, smaller potatoes than the English kind are served out, occasioning still more waste.

where the Germans passed over a country previously nearly exhausted by the French. The principal defect was the great uncertainty and irregularity of the supplies; some corps received too much, others too little, and the hospitals especially, which had not men to send out to get supplies, were particularly badly off. The quality of the food was also often bad; so that, as far as the health of the troops is concerned, the system of supplies by requisition should be as little used as possible. It must be noted, however, here, that the Germans did not pay ready money, which might, perhaps, have attracted better supplies than the system of written vouchers. The magazine supplies were excellent, but occasionally failed in certain articles, as fresh meat, as a substitute for which the celebrated pea-sausage was issued. But it was found that if the pea-sausage was used too exclusively, the men disliked it. In fact, one of the greatest difficulties was the too great uniformity of the food. To do away with this, bacon, preserved and smoked meat, peas and white beans, and potatoes, when possible, were issued as a change of diet. Independent of these extra issues, the daily German ration was as follows, in English weights:—

| | | |
|---|---|---|
| | Bread, | 26½ ounces, or biscuit, 17 ounces. |
| One of these | Fresh or salt meat, | 13 „ |
| | Salted beef or mutton, | 9 ounces, or |
| | Bacon, | 5¾ ounces. |
| | Rice, | 4·4 „ |
| One of these | Barley or greats, | 4·4 „ |
| | Peas or beans, | 8·8 „ |
| | Flour, | 8·8 „ |
| | Potatoes, | 3·3 lb |
| | Salt, | ·7 ounce. |
| | Coffee, | ·7 ounce of unroasted, or<br>1 ounce of roasted. |

The want of knowledge of cooking was very great, and also the addition of articles to give flavour, as vinegar and spices, would have been much prized. Roth strongly recommends the establishment of a school for cooking, like that at Aldershot.

The bread, owing to the long time it was on transport, was sometimes mouldy.

AUSTRIAN SOLDIER. (*Kraus, quoted by Roth.*)

*In time of Peace (in ounces avoir.)**

| | Total. | Water. | Nitrogenous substances. | Fatty substances. | Starchy substances. |
|---|---|---|---|---|---|
| Bread, | 31·00 | 12·40 | 2·47 | 0·465 | 15·25 |
| Meat (without bone), | 6·60 | 4·95 | 0·99 | 0·562 | ... |
| Suet, | 0·62 | 0·06 | ... | 0·565 | ... |
| Flour of different grains (or vegetables), | 2·48 | 0·37 | 0·27 | 0·050 | 1·75 |
| | 40·70 | 17·78 | 3·73 | 1·642 | 17·00 |

Total solids (water-free food) = 22·372. To this are added, garlic, onions, vinegar, and $\frac{6}{16}$ oz. of salt.

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* The totals are [illegible] are calculated from the table at page 195. Roth gives an average of nitrogenous substances 3·93, fat 2·016, and starch 16·4.

The amount is pretty good, but there is too great a preponderance of bread, and there is too great sameness. The fat is in too small a quantity; the nitrogenous substances are too small.

*In time of War.*—It is difficult to calculate the daily ration, as there is a weekly issue of many substances. On four days, fresh pork is issued; the total amount being 26 oz., or 6½ oz. daily. On one day, 6 oz. of salt pork; on one day, 6 oz. of beef; and on one day, 6 oz. of smoked bacon; altogether in the week, 44 oz. of meat are issued; and in addition, 1 oz. of butter or fat.

There are also issued per week:—24½ oz. of biscuit, 147 oz. of flour for bread, 29½ oz. of flour for cooking, 5½ oz. of pickled cabbage (sour kraut), 9 oz. of potatoes, 5½ oz. of pease, and 5 oz. of barley.

Wine, brandy, and beer are also given.

### RUSSIAN SOLDIER.*

*There are* 196 *Meat days and* 169 *Fast days in the year.*

| | Meat Days. | Fast Days. | |
|---|---|---|---|
| | Meat with Schtschi and Gruel, 196 days. | Schtschi and Gruel, 117 days. | Peas and Gruel, 52 days. |
| Meat, | 7 oz. Eng. | ... | ... |
| Bread (Rye), | 42 ,, | 42 oz. | 42 oz. |
| Sour kraut (and sliced cabbage), | 14·5 fl. oz. | 14·5 fl. oz. | ... |
| Chervil (*Cerefolium*, an aromatic herb, fresh), | ... | 1·1 oz. | ... |
| Peas, | ... | ... | 2·33 fl. oz. |
| Oats (unhusked), | 0·5 fl. oz. | 0·7 fl. oz. | 0·28 fl. oz. |
| Flour, | 0·7 fl. oz. | 0·7 fl. oz. | ... |
| Onions, | 0·2 fl. oz. | 0·3 fl. oz. | 0·5 fl. oz. |
| Pepper, | 3 grs. | 3 grs. | 3 grs. |
| Bay leaves, | 3 grs. | 3 grs. | 3 grs. |
| Vegetable oil, | ... | ¼ fl. oz. | ... |
| Water, | 70 fl. oz. | 70 fl. oz. | 70 fl. oz. |
| Butter, | 0·6 oz. | ... | ... |
| Lard, | ... | 0·5 oz. | 0·5 oz. |
| Salt, | 1·86 oz. | 1·86 oz. | 1·86 oz. |
| Buckwheat, | 1·87 fl. oz. | 1·87 fl. oz. | 1·87 fl. oz. |

On the march, 1¾ ℔ biscuit (24½ English oz.) instead of bread. Brandy only on rare occasions, calculated at 135 fluid ounces per year (in 5 oz. rations).

*Sepoy Diet.*—Dr Godwin has calculated the diet of a Hindu, such as a Sepoy servant, to consist of 4·387 oz. of albuminates; 1·278 oz. of fat; 18·584 oz. of carbo-hydrates; and ·64 oz. of salts—total water-free food, 25·113 oz. It is thus a really better diet than that of the European soldier. The principal articles were—24 oz. of attar (ground wheat), 4 oz. of dholl (pea), and 1 oz. of ghee (butter). In other cases rice is more or less substituted for wheat. The Hindu diet consists of wheat, or of some of the millets (cholum, raggee, cumboo—see Millets), rice, leguminosæ (*Cajanus indicus*), with green vegetables, oil, and spices. If any kind of diet of this sort has to be calculated, it can be readily done by means of the analysis of the usual foods previously given. For example, a Hindu prisoner at labour in Bengal receives, under Dr Mouat's dietary,* the following diet during his working days :—

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* From Dr Oscar Heyfelder's The Russian Camp at Krasnoe Selo, German edition, 1868. The gruel is made of boiled buckwheat, &c. Schtschi is made of soup and sour kraut well boiled together. The amount of bread seems large, but it may be watery.

| | Total. oz. | Water. oz. | Album. oz. | Fat. oz. | Starches. oz. | Salt. oz. |
|---|---|---|---|---|---|---|
| Rice, . . . . . | 20 | 2 | 1 | ·16 | 16·74 | ·1 |
| Dholl (a pea, *Cajanus indicus*), . . | 4·25 | ·4 | ·9 | ·08 | 2·75 | ·12 |
| Vegetables (reckoned as cabbage), . . | 6 | 5·46 | ·12 | ·03 | ·34 | ·04 |
| Oil, . . . . . | ·33 | ... | ... | ·33 | ... | ... |
| Salt, . . . . . | ·33 | ... | ... | ... | ... | ·33 |
| Spices, . . . . | ·33 | ... | ... | ... | ... | ... |

In some Bengal prisons, 2 ounces of fish or flesh appear to be also given.

In the Looshai expedition the Sepoys received—rice, 1 lb; flour, 1 lb; ghee, 2 oz.; salt, 1·5 oz.† The nutritive value, if the ghee is calculated as butter, is 181 grains of nitrogen and 6160 of carbon, which would appear to be a good diet in respect of carbon. Probably some peas were added.

## SECTION III.

## CLOTHING OF SOLDIERS.

The structure and examination of fabrics has been already given (page 423).

*Regulations.*—No specific instructions are laid down in the Medical Regulations respecting clothing, but the spirit of the general sanitary rules necessarily includes this subject also. When an army takes the field, the Director-General is directed to issue a code for the guidance of medical officers, in which clothing is specifically mentioned; and the sanitary officer with the force is ordered to give advice in writing to the commander of the forces, on the subject of clothing among other things.

Formerly a certain sum, intended to pay for the clothing of the men, was allotted by Government to the colonels of regiments. This was a relic of the old system by which regiments were raised—viz., by permitting certain persons to enlist men, and assigning to them a sum of money for all expenses. The colonel employed a contractor to find the clothes, and received from him the surplus of the money after all payments had been made. A discretionary power rested with the service officers of the regiment, who could reject improper and insufficient clothing, and thus the interests of the soldier were in part protected.‡ The system was evidently radically bad in principle, and, since the Crimean war, the Government has gradually taken this department into its own hands, and a large establishment has been formed at Pimlico, where the clothing for the army is now prepared. This system has worked extremely well; the materials have been both better and cheaper, and important improvements have been and are still being introduced into the make of the garments, which cannot fail to increase the comfort and efficiency of the soldier.

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* See Mouat's elaborate report On the Diet of Bengal Prisoners, Government Return, 1860, p. 49. The chittack is reckoned as the bazaar chittack—viz. = ·1283 lb, or nearly 2 ounces avoir. Some useful information on prison and coolie diets will be found in a memorandum prepared by Surg.-Major I. B. Lyon, F.C.S., Chemical Examiner to the Government at Bombay, May, 1877.

† Indian Med. Gazette, March 1, 1872.

‡ But this safeguard was not sufficient. Officers are not judges of excellence of cloth; for this it requires special training. As Robert Jackson said sixty years ago: "Soldiers' clothing is inspected and approved by less competent judges than those who purchase for themselves."

At the Pimlico depôt the greatest care is taken to test all the materials and the making up of the articles; the viewers are skilled persons, who are believed to be in no way under the influence of contractors.

In January 1865 a warrant was issued* containing the regulations for the clothing of the army, and several circulars have been since promulgated.

When a soldier enters the army he is supplied with his kit; some articles are subsequently supplied by Government, others he makes good himself. In the infantry of the line a careful soldier can keep his kit in good order at a cost of about £1 per annum. The following are the articles of the kit supplied to the infantry recruit:—

*Articles of the Kit (Infantry).*

1 Forage cap,
1 Serge frock.
1 Stock.
2 Flannel shirts.†
3 Pairs socks.
1 Razor.
Mitts.
Knife, fork, and spoon.
Sponge.
Blacking (one tin).
2 Towels.
1 Knapsack.
2 Pairs boots.
1 Pair braces.
1 Comb.
1 Clothes brush.
2 Shoe brushes.
1 Shaving brush.
1 Button stick.
1 Hold-all.

To the Army Hospital Corps and Artillery, a waterproof bag, for part of the kit, is also issued to each man. Squad bags are issued to infantry, four to each company, to hold the surplus kit.

The kit is divided ("Queen's Regulations," section 10, par. 608) into the surplus and the service kit. The former, consisting of 1 shell-jacket, 1 pair of socks, 1 shirt, 1 towel, 2 brushes, and such articles for the hold-all as are not wanted, is carried for the men. The service kit is supposed to be carried by the man, either on his person or in his knapsack (see EQUIPMENT).

Certain articles are also issued free of expense at stated intervals. For the particulars of these, reference must be made to the Royal Warrant of 1865, where they are stated in detail. The following are the articles issued to the line infantry soldier at home:—

| | |
|---|---|
| One chaco and cover, . . . . . . | Triennially. |
| One tunic, . . . . . . . . | Annually. |
| One pair cloth trousers, . . . . . | Annually. |
| One pair serge trousers in line regiments, or one pair tartan trousers in rifle regiments, . | Biennially. |
| Two pairs of boots, one on 1st April, and one on 1st October, . . . . . . | Annually. |
| One silk sash for sergeants, . . . . | Every two years. |
| One worsted sash for serjeants, . . . | Every two years. |

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* Revised Royal Clothing Warrant, 1865; another Warrant was issued in 1873, referring chiefly to recruits, and again in 1877, in reference to issues in warm climates.

† By a circular, November 1865, flannel shirts only are ordered to be supplied to the recruit.

*In India and the West Indies, and other tropical stations*, light clothing of different kinds is used—drill trousers and calico jackets, or in India complete suits of the khakee, a native grey or dust-coloured cloth, or tunics of red serge, and very light cloth. The khakee is said not to wash well, and white drill is superseding it. The English dress is worn on certain occasions, or in certain stations. Formerly the home equipment was worn even in the south of India; but now the dress is much better arranged, and also differences of costume for different places and different times of the year are being introduced.

*During Campaigns* extra clothing is issued according to circumstances. In the Crimea the extra clothing was as follows for each man :—

2 Jersey frocks.
2 Woollen drawers.
2 Pairs woollen socks.
2 Pairs woollen mitts.
1 Cholera belt.
1 Fur cap.
1 Tweed lined coat.
1 Comforter.

To each regiment also a number of sheepskin coats was allowed for sentries.

The warrant of 1865 orders the following articles of clothing to be issued to every 100 men proceeding on active service in cold, temperate, or hot climates :—

1. *In cold climates*—

| | Per 100 effectives. | | Per 100 effectives. |
|---|---|---|---|
| Sheepskin coats, | 8 | Stocking, woollen, | pairs, 200 |
| Fur caps, | 100 | Drawers, flannel, | „ 200 |
| Woollen comforters, | 100 | Cholera belts, flannel, | 200 |
| Shirts, grey flannel, | 200 | Mittens, lined with lambskin or fur, | pairs, 100 |
| Jerseys, blue, | 100 | | |
| Boots, knee, brown leather, pairs, | 100 | | |

2. *In temperate climates*—

| | | | |
|---|---|---|---|
| Shirts, flannel, of a light texture, | 200 | Waterproof capes, | 10 |
| Cholera belts, when not included in the voyage kit, | 200 | Watch coats, | 3 |

3. *In tropical climates*—

| | |
|---|---|
| Shirts flannel, of lightest texture, | 200 |
| Chaco covers, of white cotton, except in climates where the wicker helmet and "Puggaree" (turban) are to be worn, | 100 |
| Forage-cap covers, of white cotton. | 100 |
| Frock coats, of red, green, or blue serge, when not supplied as ordinary clothing of these climates, | 100 |
| Cholera belts, of flannel, when not part of the sea kit, | 200 |
| Capes, waterproof, | 10 |

## SECTION IV.

## ARTICLES OF CLOTHING.

1. *Underclothing*, viz., vests, drawers, shirts, stockings, flannel belts, &c.

The soldier, as a rule, wears as underclothing only a shirt and socks. He is obliged to have in his kit two shirts. There has been much discussion as to the respective merits of cotton and flannel shirts. Almost all medical officers prefer the latter, but their cost, weight, difficulty of cleaning, and shrinking in washing, have been objections to its general adoption. Colonel A. Herbert solved the difficulty by issuing a shirt which is partly wool, partly cotton; it is lighter and cheaper than wool, as durable as cotton, and does not shrink in washing. It is of soft even texture, and weighs 19 ounces. Under the microscope, I counted from 45 to 47 per cent. of wool.

In time of war, shirts may be partially cleaned in this way: The soldier should wear one and carry one; every night he should change; hang up the one he takes off to dry, and in the morning beat it out and shake it thoroughly. In this way much dirt is got rid of. He should then carry this shirt in his pack during the day, and substitute it for the other at night. If in addition great care is taken to have washing parades as often as possible, the difficulty of cleaning would be avoided.

For hot countries, the common English flannels are much too thick and irritating; flannel must be exceedingly fine, or what is perhaps better, merino hosiery, which contains from 20 to 50 per cent. of cotton, could be used. The best writers on the hygiene of the tropics (Chevers, Jeffreys, Moore) have all recommended flannel.

The soldier wears no drawers, but in reality it is just as important to cover the legs, thighs, and hips with flannel as the upper part of the body. Drawers folding well over the abdomen form, with the long shirt, a double fold of flannel over that important part, and the necessity of cholera belts or kummerbunds is avoided. Cholera belts are made of flannel, and fold twice over the abdomen.

The soldiers' socks are of cotton; it would be desirable to have them either all of wool, or half cotton half wool; they should be well shrunken before being fitted on. It has been proposed to divide the toes, but this seems an unnecessary refinement. It has been also proposed to do away with stockings altogether, but with the system of wearing shoes, it is difficult to keep the feet perfectly clean. The boots get impregnated with perspiration. Some of the German troops, instead of stockings, fold pieces of calico across the foot when marching; when carefully done, this is comfortable, but not, I believe, really better than a good sock kept clean.

2. *Outer Garments.*—The clothes worn by the different arms of the service, and by different regiments in the same branch, are so numerous and diverse, that it is impossible to describe them. In many cases taste, or parade, or fantasy simply, has dictated the shape or the material. And diversities of this kind are especially noticeable in times of peace. When war comes with its rude touch, everything which is not useful disappears. What can be easiest borne, what gives the most comfort and the greatest protection, is soon found out. The arts of the tailor and the orders of the martinet are alike disregarded, and men instinctively return to what is at the same time most simple and most useful. It will be admitted that the soldier intended for war should be always dressed as if he were to be called upon the next moment to take the field. Everything should be as simple and effective as possible; utility, comfort, durability, and facility of repair, are the principles which should regulate all else. The dress should not be encumbered by a single ornament, or embarrassed by a single contrivance which has not its use. Elegant it may be, and should be, for the useful does not exclude, indeed often implies, the beautiful, but to the eye of the soldier it can be beautiful only when it is effective.*

---

* La tenue, dans laquelle le militaire est prêt à marcher à l'ennemi, est toujours belle. (Vaidy).

*Head-Dress.*—The head-dress is used for protection against cold, wet, heat, and light. It must be comfortable; as light as is consistent with durability; not press on the head, and not to be too close to the hair; it should permit some movement of air over the head, and therefore openings, not admitting rain, must be made; it should present as little surface as possible to the wind, so that in rapid movements it may meet the least amount of resistance. In some cases it must be rendered strong for defence; but the conditions of modern war are rendering this less necessary.

As it is of great importance to reduce all the dress of the soldier to the smallest weight and bulk, it seems desirable to give only one head-dress, instead of two, as at present. Remembering the conditions of his life, his exposure, and his night work, the soldier's head-dress should be adapted for sleeping in as well as for common day-work. Another point was brought into notice by the Crimean war; in all articles of clothing, it much facilitates production, lessens expense, and aids distribution, if the different articles of clothing for an army are as much alike as possible; even for the infantry, it was found difficult to keep up the proper distribution of the different insignia of regiments.

*Head-Dress of the Infantry.*—The present head-dresses are the bearskin caps for the Guards, a smaller and rather lower kind for Fusiliers, busbies for the Foot Artillery, Engineers, and Rifles, the Highland bonnets and shakos* for the Line, and forage caps made of cloth for all. The bearskin weighs 37 ounces; the Engineers' busby, 13½ ounces; the Infantry shako, 9¾ ounces. It is for the professional soldier to decide if the rapid movements and the necessity of cover in modern war are compatible with the retention of the bearskin or tall busby. If not, I believe no one would wish to retain them on sanitary grounds; they are heavy, hot, give little shelter from rain, and oppose a large surface to the wind.

The present shako (now about to be discontinued) is the best that has been issued; it is made of two pieces of waterproof cloth, sewn together by the sewing-machine; its shape is slightly conical; its height is 4 inches in front, 6½ behind; weight, 9¾ ounces, including the ball and brass plate, which weigh 1¾ ounce. The oilskin cover weighs in addition 1½ ounce. The peak is horizontal, and measures 2¼ inches. There is no rim behind to direct off the rain, but the lower edge of the cap comes well down over the head.

The Glengarry Scotch cap, with a peak and a waterproof falling flap behind, and with ear-flaps, to be put down in case of rain, or in sleeping out at night, has these great advantages. It is very soft and comfortable, presses nowhere on the head, has sufficient height above the hair, and can be ventilated by openings if desired; it cannot be blown off; it can be carried at the top of the head when desired in hot weather, or pulled down completely over the forehead and ears in cold; with a large flap behind, and ear-flaps, its makes what the soldier wants, a comfortable night-cap, sheltering the back and sides of the neck as well as the head. It is also both an elegant and a national head-dress. Divested of the showy but objectionable feather, which has been foisted in the Highland regiments on the original bonnet, it would be the best head-dress in any army for temperate and subtropical climates. It has now been introduced for forage caps by Colonel Herbert; and there can be no doubt that, if a good waterproof cover with flaps is added for active service, it will be the only head-dress used in war. Unfortunately, either to save cloth or from some idea of smartness, it is now being made so small that its advantages are imperilled, as it cannot be drawn down over the head.

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* The shako is now being replaced by a helmet with a spike, on the German pattern.

The peak of the shako in the English army was worn quite horizontally about forty years ago; it was then made almost vertical, and is now horizontal again. It is perhaps now too horizontal, as it does not shade the eyes at all when the sun is low; a moderate curve would be better.

*Head-Dress of the Cavalry.*—The Horse Artillery and Cavalry carry helmets and caps of different kinds.

The shape of the helmet in the Guards and heavy dragoons is excellent. It is not top-heavy; offers little surface to the wind; and has sufficient but not excessive height above the head. The material, however, is objectionable. The metal intended for defence makes the helmet very hot and heavy; and the helmet of the Cavalry of the Guard weighs 55 ounces avoir.; that of the Dragoon Guards, 39 ounces (in 1868). But as every ounce of unnecessary weight is additional unnecessary work thrown on the man and his horse, it is very questionable whether more is not lost than is gained by the great weight caused by the metal. Leather is now often substituted in some armies, where the cavalry helmets are being made extremely light.

The Lancer cap weighs 34½ ounces; the Hussar, 29¾ ounces. Both are dresses of fantasy. The Lancer cap, except for its weight, is the better of the two; is more comfortable; shades the eyes; throws off the rain better; and offers less resistance to moving air than the Hussar cap.

The undress or forage cap of all corps is a cloth cap, with or without a peak, and varying in shape and kind, according to the regiment, and weighing about 5 ounces.

In Canada, a fur cap is used, with flaps for the ears and sides of the face and neck.

In India, many contrivances have been used. Up to the year 1842 little attention seems to have been paid to the head-dress of the infantry, and the men commonly wore their European forage caps. In 1842 Lord Hardinge issued an order, that white cotton covers should be worn over all caps; subsequently, a flap to fall down over the back of the neck was added. The effect of the cotton cover is to reduce the temperature of the air in the cap about 4° to 7° Fahr. Although a great improvement, it is not sufficient.

Afterwards other plans came into use. Pith and bamboo wicker helmets, covered with cotton, have been much used; especially the latter, which are very light, durable, not easily put out of shape, and cheap. The rim should not be horizontal, but inclined, so as to protect from the level rays of the sun. The pith, or "Sola" hats, appear to be decidedly inferior to the wicker helmets; and men have had sun-stroke while wearing them.

The turban has never been much worn in India by the English. It requires some time and care to put on; and if not well arranged, is hotter than the wicker helmet.

In the French infantry the shako is now made of leather and pasteboard, and is divested of all unnecessary ornament, so as to be as light as it can be. It comes well back on the head, being prolonged, as it were, over the occipital protuberance.

In Algeria, the Zouaves, Spahis, and Tirailleurs wear the red fez, covered with a turban of cotton. In Cochin-China, the French have adopted the bamboo wicker helmet of the English.

The natural hair of the head is a very great protection against heat. Various customs prevail in the East. Some nations shave the head, and wear a large turban; others, like the Burmese, wear the hair long, twist it into a knot at the top of the head, and face the sun with scarcely any turban. The Chinaman's tail is a mere mark of conquest. The European in India generally has the hair cut short, on account of cleanliness and dust. A small wet handkerchief, or piece of calico, carried in a cap with good ventilation, may be used with advantage; and especially in a hot land-wind cools the head greatly.

*Cravat or Neckcloth.*—Few things have given rise to more controversy than the question of the utility of the English soldier's stiff stock. In the days when the stock was at its worst, it was composed of extremely stiff leather, so hard and firm that it was impossible to bend the neck. It rubbed against and irritated the submaxillary glands, and was so uncomfortable that it was months before recruits could wear it with ease. Recruits were sometimes made to sleep in it, in order to accustom them to it more quickly. Of late years the stock has been made lower, and more flexible; and this modified stock is still worn in England, though it is now quite discarded in India, where a thin handkerchief takes its place.

It certainly seems wonderful that an apparatus of this kind should have found defenders; for it was not merely uncomfortable, and somewhat impeded the return of blood through the external jugulars, and hindered the action of some of the accessory muscles of respiration, but also (what would be more perceptible to soldiers) rendered impossible the bending and varying attitudes of the neck, which occur when a man makes a strong exertion. For great exertion with the upper extremities cannot be made if the clavicles and scapula are not rigidly fixed; and they cannot be fixed unless the neck can easily bend. On every account, physiological and mechanical, the neck should be left bare, or be protected without any pressure. Nor is there any medical reason why it should not be left bare. Like the face, the neck soon gets accustomed to exposure; and besides, if we let Nature follow her own course, there is the beard to shelter important parts.

If the neck is covered at all, it should be with a very thin and supple cloth. The collar of the coat should be made low and loose, so as to give full freedom to every moment of the neck, and not to compress the root of the neck in the slightest degree.[*]

In Algeria the French troops have long worn a thin cravat of cotton; and a decree of March 1860 extended its use to all the corps of infantry.

*Coat, Tunic, Shell-Jacket, &c.*—The varieties of the coat are very numerous in the army; and there are undress and stable suits of different kinds. The infantry now wear the tunic, which is a great improvement over the old cut-away coatee. It is still, however, too tight, and made too scanty over the hips and across the abdomen. A good tunic should have a low collar, and be loose round the neck, over the shoulders (so as to allow the deltoid and latissimus the most unrestricted play),[†] and across the chest. It should come well across the abdomen, so as to guard it completely from cold and rain; descending loosely over the hips, it should fall as low over the thighs as is consistent with kneeling in rifle practice, *i.e.*, as low as it can fall without touching the ground. Looking not only to the comfort of the soldier, but to the work and force required of him, it is a great mistake to have the tunic otherwise than exceedingly loose. A loose tunic, a blouse in fact, is in reality a more soldier-like dress than the tight garment, which every one sees must press upon and hinder the rapid action of muscles. The tunic should be well provided with pockets, not only behind, but on the sides and in front; the pockets being internal, and made of a very strong lining. In time of war, a soldier has many things to carry; food, extra ammunition sometimes, all sorts of little comforts, which pack away easily in pockets. If the appearance is objected to, they need not to be used in time of peace, but with a loose dress, they would not be seen.

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[*] Mr Myers of the Coldstream Guards, has directed special attention to this and other points connected with the stiff dress, especially with the tight tunic and collar. He even thinks the present stock worse than the old very stiff high one, which, if it be pressed on the chin, was so stiff that it was loose about the neck.

[†] This cannot occur if epaulets are worn; and it is to be hoped nothing will ever occur to bring in again the use of these so-called ornaments.

A great improvement was made by Colonel Herbert. The old shell-jacket was done away with, and a loose frock substituted. As this is sure to become the working dress, and the tunic will be kept for parades merely, the soldier will have the great advantage of a loose dress.

In India the tunic is made loose, and of thin material.

*Waistcoats.*—No waistcoats are worn in the British army, but they ought to be introduced.* A long waistcoat with arms is one of the most useful of garments; it can be used without the tunic when the men are in barracks or on common drill. Put on under the tunic, it is one of the best protections against cold. At present the men are obliged to wear tight coats, and having nothing under them, line them with flannel and wadding. In winter and summer they often wear the same dress, although the oppression in the summer is very great. If the tunic were made very loose of some light material, and if a good short Jersey or Guernsey frock were allowed to be worn at the option of the men, the men would have cool dresses in summer, warm in winter, and the thin tunic would be more comfortable in the Mediterranean and subtropical stations.

*Trousers.*—Formerly the army wore breeches and leggings; but shortly before or during the Peninsular war trousers were introduced. The increased comfort to the soldier is said to have been remarkable; the trouser, indeed, protecting the leg quite down to the ankle, seems to be as good a dress as can be devised, if it is made on proper principles, viz., very loose over the hips and knees, and gathered in at the ankle, so that merely sufficient opening is left to pass the foot through. The much-laughed-at pegtop trousers seem to be, in fact, the proper shape. In this way the whole leg is protected, and the increased weight given by the part of the trousers below the knee is a matter of no consequence.

The trousers are supported either by braces or a belt. If the latter be used, it should be part of the trousers, should fit just over the hip, and not go round the waist. It must be tight, and has one disadvantage, which is, that in great exertion the perspiration flowing down from above collects there, as the tight belt hinders its descent; also, if heavy articles are carried in the pocket, the weight may be too great for the belt. Braces seem, on the whole, the best.

Trousers should be made with large pockets, on the principle of giving the men as much convenience as possible of carrying articles in time of war.

In India, trousers are made in the same fashion as at home, but of drill or khakee cloth, or thin serge—an excellent material, especially for the northern stations.

*Leggings and Gaiters.*—Formerly long leggings reaching over the knees, and made of half-tanned leather, were used. They appear not to have been considered comfortable, and were discarded about sixty years ago. Short gaiters were subsequently used for some time, but were finally given up, and for several years nothing of the kind was worn. After the Crimean war Lord Herbert introduced for the infantry short leather leggings, 6 inches in height, and buttoning on the outside. These were not of good length or shape, and have now been superseded by leggings which come more up to the knee, and are much more serviceable.

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* A waistcoat was introduced a short time ago, but has since been unfortunately withdrawn again.

In some of the French regiments a gaiter of half-dressed hide comes up to just below the knee; short calico or linen gaiters are worn by other corps; a flap comes forward over the instep. The calico gaiters have been much praised, but they soon get saturated with perspiration, thickened in ridges, and sometimes irritate the skin. On the other hand, leather gaiters, if not made of good leather, lose their suppleness, and press on the ankles and instep.

A great advantage of gaiters and leggings is, that at the end of a march they can be at once removed and cleaned; but, on the whole, if suitable leather could be fixed at the bottom of trousers, it seems to me they might be abandoned.

*Shoes and Boots.*—In the action of walking the foot expands in length and breadth; in length often as much as $\frac{1}{10}$th, in breadth even more. In choosing shoes this must be attended to. The shoemaker measures when the person is sitting, and as a rule allows only $\frac{1}{24}$th increase for walking. Ankle boots, weighing 40 to 42 ounces, are now worn by the infantry: the cavalry have Wellingtons and jackboots. The jackboots of the Life Guards weigh (with spurs) 100 ounces avoir. Shoes cannot be worn without gaiters. Ankle boots are preferable; in the English army they are now made to lace, and are fitted with a good tongue. Great attention is now paid at Pimlico to the shape and make of the boot, and the principles laid down by Camper, Meyer, and others, are carefully attended to. There are eight sizes of length and four of breadth, making thirty-two sizes in all. The boots are made right and left. The heel is made very low and broad, so that the weight is not thrown on the toes, the gastrocnemii and solei can act, which they cannot do well with a high heel, and there is a good base for the column which forms the line from the centre of gravity, and the centre of gravity is kept low; the inner line of the boot is made straight, so as not to push outwards the great toe in the least degree, and there is a bulging over the root of the great toe to allow easy play for the large joint. Across the tread and toes the foot is made very broad, so that the lateral expansion may not be impeded; the toes are broad. Great care is taken in the inspection of the boots, the order of inspection being—1*st*, The proof of the size, which is done by standard measure; 2*d*, The excellence of the leather, which is judged of by inspection of each boot, and by selecting a certain number from each lot furnished by a contractor, and cutting them up; if anything wrong is found, the whole lot is rejected; 3*d*, The goodness of the sewing; there must be a certain number of stitches per inch (not less than eight for the upper leathers), a certain thickness of thread, and the thread must be well waxed. The giving up of boots is generally owing to the shoemaker using a large awl, and thin unwaxed thread, with as few stitches as possible; the work is thus easier to him, but the thread soon rots.

The Germans are now introducing a long boot, with a slit down the centre; it can be worn under the trousers, or at pleasure outside, as the slit opens, and can then be laced. A somewhat similar boot has been invented by Major Sir W. Palliser.

Considering the great injury inflicted on the foot by tight and ill-made boots, by which the toes are often distorted and made to override, and the great toe is even dislocated and anchylosed, it is plain that the increased attention lately excited on this point is not unnecessary. The compression of children's feet by the tight leather shoes now made is extremely cruel and injurious. It may, indeed, be asserted that the child's foot would be better if left altogether unclothed, and certainly we see no feet so well modelled as the children of the poor, who run about shoeless. In the case of the soldier, too, who has in many campaigns been left shoeless, and has greatly suffered therefrom, it is a question whether he should not be trained to go barefooted. The feet soon get hard and callous to blows, and cleanliness is really promoted by having the feet uncovered, and by the frequent washings the practice renders necessary. After being unworn for some time, shoes that previously fitted will be found too small, on account of the greater expansion of the foot, and this is itself an argument against the shoe as commonly worn.

The sandal in all hot countries is much better than the shoe, and there is no reason why it should not be used in India for the English soldiers as it is by the native; the foot is cooler, and will be more frequently washed. For all native troops, negroes, &c., the sandal should be used, and the boot altogether avoided. In campaigns it is most important to have large stores of boots at various points, so that fresh boots may be frequently issued, and worn ones sent back for repair. Soldiers ought to be trained to repair their own boots.*

*Greatcoat and Cloak.*—In the cavalry, cloaks, with capes which can be detached, are carried. They are large, so as to cover a good deal of the horse, and are made of good cloth; the weight is about 5 ℔ to 6 ℔ for the cloak, and 2½ ℔ to 3 ℔ for the cape. The infantry wear greatcoats weighing from 5 ℔ to 6 ℔.† They are now made of extremely good cloth, are double-breasted, and are as long as can be managed. They are not provided with pockets at the back, which is a serious omission, and they also should have loops, so that the flaps may be turned back if desired. They are too heavy, and absorb a great deal of wet, so that they dry slowly. General Eyre's Committee on Equipments recommended a lighter greatcoat, and in addition a good waterproof cape. The suggestion seems to be a very good one.‡ A hood might also be added with advantage. In countries with cold winds they are a great comfort. Or the Russian bashlik might be introduced; it is a most useful covering for cold and windy countries.

The greatcoat is perhaps the most important article of dress for the soldier. With a good greatcoat, Robert Jackson thought it might be possible to do away with the blanket in war, and if india-rubber sheets were used this is perhaps possible. In the Italian war of 1859, the French troops left their tunics at home, and campaigned in their greatcoats, which were worn open on the march.§

In countries liable to great vicissitudes of temperature, and to sudden cold winds, as the hilly parts of Greece, Turkey, Affghanistan, &c., a loose, warm cloak, which can be worn open or folded, is used by the inhabitants, and should be imitated in campaigns. It is worthy of remark, that in most of these countries, though the sun may be extremely hot, the clothes are very warm.

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* It may be worth while to give a receipt for making boots impermeable to wet. I have tried the following and found it effectual:—Take half a pound of shoemaker's dubbing, half a pint of linseed oil, half a pint of solution of india-rubber (price 8s. per gallon). Dissolve with gentle heat (it is very inflammable), and rub on the boots. This will last for five or six months; but it is well to renew it every three months. At a small expense the boots of a whole regiment could be thus made impermeable to wet. Army Circular, clause, 66, 1875, directs—1, That boots are to be blackened with three coats of ordinary blacking, instead of other substances. 2. Boots or shoes in store are to be [illegible], or have neat's-foot oil applied to uppers, at least, once in four months.

† I weighed three—one large size, one medium, and one small; the weights were 6 ℔ 8 ounces, 5 ℔ 9 ounces, and 5 ℔ 8 ounces.

‡ Clause 155, 1876, of Army Circulars directs the issue of a water-proof coat for certain duties.

§ Cloth may be made waterproof by the following simple plan:—Make a weak solution of glue, and while it is hot add alum in the proportion of one ounce to two quarts; as soon as the alum is dissolved, and while the solution is hot, brush it well over the surface of the cloth, and then dry. It is said that the addition of two drachms of sulphate of copper is an improvement.

In very cold countries, sheepskin and buffalo-hide coats, especially the former, are very useful. No wind can blow through them; in the coldest night of their rigorous winter the Anatolian shepherds lie out in their sheepskin coat and hood without injury, though unprotected men are frozen to death. In Bulgaria, the Crimea, and other countries exposed to the pitiless winds from Siberia, and the steppes of Tartary, nothing can be better than coats like these.*

## SECTION V.

## WEIGHTS OF THE ARTICLES OF DRESS AND OF THE ACCOUTREMENTS, AND ON THE MODES OF CARRYING THE WEIGHTS.

The following tables give the weights of all the articles used by a Heavy Cavalry Regiment, an Hussar Regiment, and the Infantry of the Line. The weights carried by the Artillery are much the same as those of the Cavalry. The weights of the helmets and jackboots of the Life and Horse Guards have been already mentioned. The cuirass weighs 10 ℔ 12 oz.; it rests a little on the sacrum and hip, and in that way is more easily borne by the man. With these exceptions, the weights may be considered nearly the same as those of the heavy dragoons.

### CAVALRY.

The weight of the accoutrements and equipment is in great part carried by the horse. The cloak, when not worn, is carried in a roll over the shoulder, or sometimes round the neck, or in front on the horse.

*Private in 6th Dragoon Guards.—Weights in Marching Order (Jan. 1872).*

| Articles. | ℔. | oz. |
|---|---|---|
| Carbine, | 6 | 8 |
| Sword-belt and sword, | 5 | 8 |
| Pouch-belt and pouch, | 1 | 8 |
| Cloak and cape, | 10 | 8 |
| Valise completely packed, | 15 | 0 |
| Saddle complete, | 47 | 8 |
| Sheepskin, corn-sack, and nose-bag, | 8 | 8 |
| Man's clothing (which includes a complete set of underclothing, helmet without plume, tunics, pants, haversack, gauntlets, knee-boots, and spurs,) | 17 | 0 |
| Carry forward, | 112 | 0 |
| Brought forward, | 112 | 0 |
| Blanket, | 4 | 4 |
| Heel Ropes, | 1 | 8 |
| ,, Pegs, | 2 | 2 |
| Shackles, | 0 | 10 |
| Collar Shank, | 0 | 13 |
| Wellington boots and spurs, | 2 | 10 |
|  | 123 | 15 |
| Average weight of man (naked), | 161 | 0 |
| Total, | 284 | 15 |

Or 20 stone and 5 ℔ (nearly).

*Weights of Men's Clothes, Necessaries, &c., 10th Royal Hussars* (1869).†

| No. | Articles. | ℔. | oz. |
|---|---|---|---|
| 1 | Tunic, | 3 | 0 |
| 1 | Busby, plume, and lines, | 1 | 13¾ |
| 1 | Pair leather overalls and straps, | 3 | 6 |
| 1 | Pair cloth do. do., | 2 | 7½ |
| 1 | Stable-jacket, | 1 | 15½ |
|  | Carry forward, | 12 | 10¾ |
|  | Brought forward, | 12 | 10¾ |
| 1 | Forage-cap, | 0 | 5 |
| 1 | Valise, | 2 | 7 |
| 1 | Cloak, 5 ℔ 8½ oz.; cape, 2 ℔ 6 oz., | 7 | 14½ |
|  |  | 23 | 5¼ |

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* Sheep-skin bags with the wool inside, were much used by the French troops during the defence of Paris, in the winter of 1870-71.

† Since this date, the only change is the substitution of long boots for booted overalls; but it is uncertain if this change will be permanent.

*Weight of Men's Clothes, Necessaries, &c., 10th Royal Hussars*—continued.

| No. | Articles. | lb. | oz. |
|---|---|---|---|
| | Brought forward, | 23 | 5¼ |
| 1 | Pair boots, | 3 | 0¼ |
| 1 | ,, spurs, | 0 | 5¼ |
| 1 | ,, highlows, | 3 | 8 |
| 1 | Stable bag, | 0 | 6 |
| 1 | Pair braces, | 0 | 3¾ |
| 1 | Button-brush, | 0 | 1½ |
| 1 | Cloth ,, | 0 | 3½ |
| 1 | Hair ,, | 0 | 2¾ |
| 1 | Brass ,, | 0 | 2¾ |
| 1 | Lace ,, | 0 | 1 |
| 1 | Shaving ,, | 0 | 1¼ |
| 2 | Shoe ,, | 0 | 7½ |
| 1 | Tin blacking, | 0 | 4½ |
| 1 | Hair-comb, | 0 | 0½ |
| 2 | Pairs drawers, each 13¾ oz., | 1 | 11½ |
| 2 | Pairs gloves, each 7¼ oz., | 0 | 14½ |
| Or 2 | ,, cotton socks, each sock 2¼ oz., | 0 | 9 |
| | Carry forward, | 35 | 8¾ |

| No. | Articles. | lb. | oz. |
|---|---|---|---|
| | Brought forward, | 35 | 8¾ |
| 4 | Brass paste, | 0 | 3½ |
| 1 | Hold-all, | 0 | 4 |
| 1 | Horse-rubber, | 0 | 11 |
| 1 | Knife, fork, and spoon, | 0 | 4½ |
| 1 | Pipe-clay and sponge, | 0 | 2 |
| 1 | Razor, | 0 | 2½ |
| 3 | Shirts, each 14½ oz., | 2 | 11½ |
| 1 | Button brass, | 0 | 1¾ |
| 1 | Stock, | 0 | 1½ |
| 2 | Towels, 7¾ oz. each, | 0 | 15½ |
| 1 | Stable trousers, | 1 | 5 |
| 2 | Flannel jackets, each 11 oz., | 1 | 6 |
| 1 | Oil tin, | 0 | 2½ |
| 1 | Pair foot-straps, | 0 | 0½ |
| 1 | Mess-tin and strap, | 1 | 1½ |
| 1 | Account-book, | 0 | 1½ |
| | | 45 | 3½ |

*Weight of Saddlery,* 10*th Royal Hussars.*

| Articles. | lb. | oz. |
|---|---|---|
| Saddle-tree, | 6 | 5½ |
| ,, seat, | 1 | 6½ |
| Pair flaps, | 2 | 8½ |
| ,, pannels, | 4 | 6½ |
| Girth-tub, | 0 | 6½ |
| Girth-leather, | 1 | 1½ |
| Stirrup-irons, | 1 | 11½ |
| ,, leathers, | 1 | 3½ |
| Crupper, | 0 | 14½ |
| Breastplate, | 1 | 4¼ |
| Surcingle, | 0 | 15 |
| Set of baggage-straps, | 0 | 9¼ |
| ,, cloak-straps, | 0 | 9½ |
| Pair wallets, | 1 | 14½ |
| Pair shoe-cases and straps, | 1 | 4 |
| 4 Horse shoes and nails, | 4 | 9 |
| New carbine bucket, | 2 | 13½ |
| Bridle-bit and head-stall, | 2 | 2 |
| Bridoon-bit and reins, | 1 | 2 |
| Curb-chain, | 0 | 3¾ |
| Bit-reins, | 0 | 10½ |
| Head-collar, | 1 | 11½ |
| Collar-chain, | 1 | 12½ |
| Sheepskin, | 4 | 4 |
| Carry forward, | 45 | 13¾ |

| Articles. | lb. | oz. |
|---|---|---|
| Brought forward, | 45 | 13¾ |
| Shabraque, | 4 | 6½ |
| Numnah, | 2 | 11¼ |
| Corn-sack, | 1 | 11¼ |
| Nose-bag, | 1 | 1½ |
| Horse-brush, | 0 | 11 |
| Curry-comb, | 0 | 11 |
| Sponge, | 0 | 2 |
| Hoof-picker, | 0 | 1¾ |
| Scissors, | 0 | 3½ |
| Horse-log, | 1 | 3¼ |
| Haversack, | 0 | 9 |
| Carbine, | 6 | 9 |
| Pouch-belt, 11¼ oz., | 3 | 8¼ |
| Pouch, 12½ oz., | | |
| 20 rounds ammunition, 32½ oz., | | |
| Waist-belt, &c., 1 lb 1 oz., | 7 | 0½ |
| Sabretash and slings, 1 lb 5½ oz., | | |
| Sword, 4 lb 10 oz., | | |
| | 76 | 7¾ |
| Weight of equipments, | 121 | 11¼ |
| Total weight of Hussar* with all his equipments, | 259<br>or 18½ st. | 6¼ |

### INFANTRY.

The articles of the infantry soldiers' kit have been already noted. The kit is divided into the service and the surplus kit, the latter being always carried for, and not by, the man. The service kit consists of the clothes he wears, and of some duplicate articles and other necessaries.

These articles consist of one shirt (12 ounces in weight if of cotton, 19

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* Average weight and height of the men in these two cavalry regiments—

| | Height. | | Weight (naked). | |
|---|---|---|---|---|
| | ft. | in. | lb. | oz. |
| 5th Dragoon Guards, | 5 | 9¼ | 161 | 0 |
| 10th Hussars, | 5 | 7¾ | 137 | 11 |

ounces if of flannel), pair of socks (4 oz.), pair of trousers (23 or 32 oz., according to kind), pair of boots (42 oz.), towel (8 oz.), hold-all, and knife, fork, and spoon (2½ oz.), 2 brushes (6 oz.), tin of blacking (6½ oz.), forage cap (4 oz.).

It is not possible to state accurately the weights of all the articles of kit and equipment, as some are now being altered, but the following table is fairly correct:—

| | Average weight in lbs. and ounces. | |
|---|---|---|
| | lbs. | oz. |
| Weight of clothes on person, including shako, winter trousers, and leggings, . . . . . . . . . . | 10 | 0 |
| Personal necessaries, viz., service kit in valise, . . . . | 7 | 3 |
| Greatcoat, . . . . . . . . . . . . | 5 | 8 |
| Valise equipment for carrying necessaries, greatcoat, and armament, viz., valise, two pouches, ball-bag, suspenders, waist-belt, frog, coat-straps, . . . . . . . . . . | 5 | 10 |
| Haversack, . . . . . . . . . . . . | 0 | 8 |
| Canteen, . . . . . . . . . . . . . | 1 | 9 |
| Armament, viz., rifle and sling (9 lb 8 oz.), bayonet (1 lb), ammunition (60 rounds, 6 lb weight=1 lb for 10 rounds nearly), | 16 | 8 |
| Water-bottle (new pattern) and water, . . . . . . | 2 | 9 |
| | 49 | 7 |

In war, food and a blanket would be also carried, adding from 6 to 8 lb to the weight. By omitting 40 rounds of ammunition and one pouch, the weight of the peace equipment is lessened to 40 lb; and if the canteen were only carried when it was wanted, the weight would be under 39 lb. If the greatcoat with the cape could be reduced to 5 lb, and the summer trousers and the boots were left out of the valise, the weight would be reduced below 35 lb, and still the soldier would have really everything necessary for his comfort.

Some experienced officers, however, consider it essential that the second pair of boots should be always carried by the soldier. No doubt a man should have a second pair of boots, and there may be circumstances in periods of peace when he might desire to have them with him; but surely there is no necessity for him to carry, as he does now, even if he only goes on guard on a fine day, a pair of boots which he never puts on. It might be left to his discretion to carry his extra boots, and it is pretty certain he will take them when they add to his comfort. So also with the second pair of trousers; why should they be constantly carried when they are scarcely ever wanted?

In time of war it is most important to have the soldier as little weighted as possible. The long and rapid marches which have so often decided wars have never been made by heavily laden men. The health also suffers. It is of national importance that the soldier should be as healthy and as efficient as possible, as the fate of a nation may be staked on the prowess of its army. The line which the weight of his necessaries should not exceed should be drawn with the utmost care; if his health suffers more by carrying some extra pounds of weight than it benefits by the comfort the articles give, why load him to his certain loss? The overdoing the necessaries of the soldier has always been a fault in our army; Robert Jackson noticed it seventy years ago. "It is a mistake," he says, "to multiply the equipment of the soldier with a view of adding to his comfort."

There are certain articles of material comfort to a man on service in a cold or wet country, and I believe some alteration in the present arrangement would be desirable. I venture to propose, therefore, some slight changes. The greatcoat, blanket, and a waterproof sheet (or portion of a shelter-tent), to keep both the coat and blanket and the man himself dry, are articles of the utmost importance; there is scarcely anything that a soldier might not di pense with sooner than these. But their weight is considerable, and it is necessary to sacrifice something else to secure them. The second pair of trousers is clearly unnecessary, and if he started with a thoroughly good pair of boots made waterproof, as can be easily done, and had a cheap loose shoe which he might put on after a fatiguing march, and if proper transport were provided for due renewal, the second pair of boots might be left out. A spare shirt, towel, socks, brushes (or better still, a small-tooth comb for the hair, which prevents vermin), a small hold-all, and a clasp-knife and spoon, would comprise all that would be necessary, in addition to his haversack, water-bottle, and provisions. The forage cap with waterproof cover should be substituted for the shako.

If such a plan were followed the weight of such a war equipment would be as follows:—

| | lb avoir. | oz. |
|---|---|---|
| Clothes on person, | 10 | 0 |
| Service kit in valise, viz., shirt (12 oz.), towel (8 oz.), soap (2 oz.), 1 brush (3 oz.), hold-all (3 oz.), socks (4 oz.), shoes (16 oz.), | 3 | 0 |
| Greatcoat, | 4 | 0 |
| Waterproof sheet (with appliances for tentage), | 4 | 0 |
| Blanket, | 4 | 0 |
| Haversack and three days' provisions, | 6 | 0 |
| Water-bottle and 20 fl. oz. of water, | 2 | 2 |
| Canteen, | 1 | 9 |
| Valise equipment, | 5 | 10 |
| Armament (with sixty rounds), | 16 | 8 |
| | 56 | 13 |

On ordinary occasions in war, as he would only carry one day's provisions and 40 rounds of ammunition, the weight would only be 52 lb. While he would be more comfortably provided, he would be less weighted than with the present system, and would be able, if it were required, to carry entrenching tools.

The valise equipment proposed by General Eyre's Committee, and which has been now adopted for the army, possesses great facilities for carrying these articles, as will be presently noticed.

This committee also recommended that, instead of the squad-bag for 25 men, each man shall have a separate canvas bag for his surplus kit, as is now provided on board ship. In time of peace this would be carried for him, as the squad-bag is at present; in time of war it would be left at home.

It is of great moment to give each man a bag for surplus kit to himself. It encourages the men to take care of their things, and enables them to pack them comfortably. The men of the Army Hospital Corps who have such bags have told me that they find them in all respects preferable to the squad-bags.*

It may be interesting to give the weights of the various articles carried by the infantry soldier of the French, Prussian, and Russian armies.

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* The weight of the clothing, equipment, and kit of the Army Hospital Corps I have had taken; they are as follows:—

| | lb. | oz. |
|---|---|---|
| Clothes on the person, including shako and leggings, | 10 | 9 |
| Greatcoat and cape, | 5 | 13 |
| Extra kit and small articles, | 8 | 2 |
| Valise with straps, belt, mess-tin, haversack, and black bag, | 8 | 1 |
| Water-bottle (new pattern) with water, | 2 | 9 |
| Field companion, complete, | 9 | 13 |
| Water-bottle for ditto, with water, | 5 | 12 |
| Total | 50 | 11 |

*Equipment of the French Infantry Soldier* (187[illegible] *Morache.*)

| Articles. | Weight in lbs. avoir. | oz. |
|---|---|---|
| A. CLOTHING, &c. | | |
| Shako, | 0 | 15¼ |
| Greatcoat, | 4 | 6½ |
| Epaulettes, | 0 | 6¼ |
| Shirt, | 1 | 0¾ |
| Neck-cloth, | 0 | 2¼ |
| Braces, | 0 | 2½ |
| Trousers, | 1 | 8¾ |
| Drawers, | 0 | 10 |
| Shoes, | 1 | 15¾ |
| Leather gaiters, | 0 | 11¾ |
| Pocket handkerchief, | 0 | 2½ |
| Knife, | 0 | 1½ |
| Spoon, | 0 | 1 |
| Total clothing, &c., | 12 | 4¾ |
| B. EQUIPMENT AND ARMAMENT. | | |
| Rifle (pattern of 1866)* | 8 | 12¾ |
| Strap for do., | 0 | 3½ |
| Cartridge pouch,<br>Belt and accessories,<br>Sword-bayonet, | 4 | 11¾ |
| 2 Packets of cartridges in pouch, | 1 | 5 |
| 2 Loose cartridges, | 0 | 2¼ |
| Total equipment, | 15 | 3¼ |
| C. PACK. | | |
| I. Knapsack empty, | 5 | 7 |
| Carry forward, | 5 | 7 |

| Articles. | Weight in lbs. avoir. | oz. |
|---|---|---|
| Brought forward, | 5 | 7 |
| II. In pack:— | | |
| 2 Shirts, | 2 | 1½ |
| 1 Pair drawers, | 0 | 10 |
| 2 Pair linen gaiters, | 0 | 5¼ |
| 1 Night-cap, | 0 | 1¼ |
| 1 Pocket handkerchief, | 0 | 2½ |
| 1 Pair shoes, | 1 | 15¾ |
| 1 Pair trousers, | 1 | 8¾ |
| Hold-all complete, | 1 | 10½ |
| 2 Pairs gloves, | 0 | 3 |
| 8 Packets cartridges, | 5 | 1 |
| Small book, | 0 | 1¼ |
| Jersey, | 2 | 3¼ |
| Tunic, | 3 | 15½ |
| Forage-cap, | 0 | 4½ |
| Small bag, | 0 | 5¾ |
| III. Camp-equipage:— | | |
| Tent, | 2 | 12½ |
| Accessories, | 1 | 3¾ |
| Blanket, | 3 | 8½ |
| Cooking-pot, | 3 | 3 |
| Mess-tin, | 0 | 14 |
| Water-bottle, empty, | 0 | 13¾ |
| IV. Four days' provisions, but only two days of salt meat or bacon,† | 6 | 7½ |
| Total, | 45 | 0¼ |
| Grand Total, | 72 | 8¼ |

The German infantry soldier carries the following weights:—‡

| | | |
|---|---|---|
| Clothing on the person (with gloves), not including helmet, | 10 | 12½ |
| Armament and equipment (including helmet, water-bottle (full), coffee-mill, and trenching tools), | 31 | 5 |
| Pack, with extra kit, &c., and reserve ammunition, | 19 | 13½ |
| Greatcoat and straps, | 5 | 11 |
| Rations, | 7 | 8½ |
| Total, | 74 | 13½ |

Some of the articles are not always carried by the same man, such as the hatchet, spade, and coffee-mill, so that the weight may be lessened to 66 lb—average weight carried, 66 lb to 71 lb. The shako of the riflemen and sharpshooters is about 3½ oz. lighter than the infantry helmet. The Mauser rifle weighs 10 lb and the bayonet 1 lb 8½ oz.

The Russian soldier carries 70½ lb, the Austrian 60 lb, and the Italian 75 lb.; the mean of European armies being 66 lb.

The mean weight of the rifles carried by European infantry is 9 lb 6 oz.; of the bayonet, 1 lb 2½ oz.; and of each cartridge, 1½ oz.

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* This has been recently altered to the Gras rifle, but apparently without change of weight.

† To this must be added for water in the water-bottle, 2 lb. 2¼ oz. and at least 1 lb. 2 oz. if the tent be damp, making a total of nearly 76 lbs

‡ Roth and Lex, op. cit., Bd. III. (1877), p. 110.

## SECTION VI.

## CARRIAGE OF THE NECESSARIES AND ARMAMENT.

The equipment of the cavalry soldier is in great part carried by the horse; but I have been informed that the mode in which the cavalry valise is arranged is not comfortable to the men. The total weight carried by the horse appears also to be large. A soldier has personal and horse equipments equal to nearly his own weight. I am not competent to pronounce on the necessity of this, but it is a fact that in light-cavalry regiments the horse now carries nearly 19 stone weight, although the rider is on average under 10 stone.

In the case of the infantry soldier, who carries the weights himself, the greatest care is necessary to place them in the manner least likely to detract from his efficiency or to injure his health. If it were possible to let a man, in European countries, carry nothing but his armament and water-bottle, as in India, much more work would be got out of him, longer marches would be made, and he would show greater endurance on the day of action. But such an arrangement is impossible, as transport could not be provided, and the alternative of leaving a man without his necessaries is not to be thought of. But it cannot be too strongly impressed on all commanding officers, that every ounce of weight saved is a gain in efficiency. The Prussians, in the war of 1866, obtained waggons whenever they could to carry the knapsacks, and the comparison between the condition of the men thus relieved and those who could not be so, was striking.* I am also convinced that a change of opinion must be brought about in the army on a very material point. Some officers believe that, as the men must carry weights in war, they ought to carry them on all occasions during peace, so that the men may be accustomed to them; and they attempt to strengthen their position by referring to the custom of the Romans, who exercised their men in peace with heavier weapons than those used in war. But this example is not applicable. A man should be exercised in the highest degree in any way which may develop his muscles and improve the circulation through his lungs and heart. Any amount of muscular exertion (within, of course, reasonable limits), any degree of practice with weapons, must be good as long as his body is unshackled; but if he is loaded with weights, and especially if the carriage of the weights at all impedes the action of the lungs and heart, then the very exertion which in other circumstances would benefit him must do him harm. The soldier must carry weights sometimes, but it should be a rule not to carry them when he has no immediate need of the various articles. The aim should be the cultivation of the breathing power of his lungs and the power of his muscles to an extent which will enable him to bear his weights, at those times when he must carry them, more easily than if, on a false notion of accustoming him to them, he had been obliged to wear them on all possible occasions.

Sufficient practice with the weights to enable a man to dispose them comfortably, and to make him familiar with them, should of course be given; but a very short teaching will suffice for this.

The weights which an infantry soldier has to carry have already been stated; the mode of disposing of them has now to be considered.

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* See Mr Bostock's able Report in the Army Medical Report, vol. vii. p. 359.

I have seen a letter from a Prussian officer, high in rank, and certain to know the *fact*, stating that the difference in the health of the Prussian soldiers who carried the knapsacks in the Bohemian marches in 1866, and those who did not, was remarkable. The men who had not carried their packs, though they had not had the comfort of their necessaries, were fresh and vigorous and in high spirits; those who had carried them, on the other hand, were comparatively worn and exhausted. And this was with the best military knapsack then known.

Weights are most easily borne when the following points are attended to:—

1. They must lie as near the centre of gravity as possible. In the upright position the centre of gravity is between the pelvis and the centre of the body, usually midway between the umbilicus and pubis, but varying of course with the position of the body; a line prolonged to the ground passes through the astragalus just in front of the os calcis. Hence weights carried on the head or top of the shoulder, or which can be thrown towards the centre of the hip bones, are carried most easily, being directly over the line of the centre of gravity. When a weight is carried away from this line the centre of gravity is displaced, and, in proportion to the added weight, occupies a point more or less distant from the usual site; until, perhaps, it is so far removed from this that a line prolonged downwards falls beyond the feet; the man then falls, unless, by bending his body and bringing the added weight nearer the centre, he keep the line well within the space which his feet cover.

In the distribution of weights, then, the first rule is to keep the weight nearer to the centre; hence the old mode of carrying the soldier's greatcoat, viz., on the back of the knapsack, is a mistake, as it puts on weight at the greatest possible distance from the centre of gravity.

2. The weights must in no case compress the lungs, or in any way interfere with the respiratory movements, or the elimination of carbonic acid, or hinder the transmission of blood through the lungs, or render difficult the action of the heart.

3. No important muscles, vessels, or nerves should be pressed upon. This is self-evident; an example may be taken from the late Regulation pack, the arm-straps of which so pressed on the axillary nerves and veins as to cause numbness, and often swelling of the hands, which I have known last for twenty-five hours.

4. The weights should be distributed as much as possible over several parts of the body.

If we consider the means made use of by those who carry great weights, we find the following points selected for bearing them:—

1. The top of the head. The cause of this obvious; the weight is completely in the line of centre of gravity, and in movement is kept balanced over it. Of course, however, very great weights cannot be carried in this way.

2. The tops of the scapulæ, just over the supra-spinous fossa and ridge. At this point the weight is well over the centre of gravity, and it is also diffused over a large surface of the ribs by the pressure on the scapula.

3. The hip bones and sacrum. Here, also, the weight is near the centre of gravity, and is borne by the strong bony arch of the hips, the strongest part of the body.*

In addition, great use is always made by those who carry great weights of the system of balance. The packman of England used to carry from 40 ℔ to even 60 ℔ easily thirty miles a-day by taking the top of the scapula for the fixed point, and having half the weight in front of the chest and half behind. In this way he still brought the weight over the centre of gravity. The same point, and an analogous system of balance, is used by the milkmaid, who can carry more weight for a greater distance than the strongest guardsman equipped with the old military accoutrements and pack.

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* The girls engaged in some of the works in Cornwall, carry immense bags or hampers of sand up steep hills by resting the lower part of the sack on the hip and sacrum, and the upper part on the scapula. It is the same position as that taken by the Turkish porters, who will carry 600 and 800 ℔. some distance; they also sometimes have a band round the forehead fastened to the top of the weight.

These points must guide us in arranging the weights carried by the soldier. The weight on the head is, of course, out of the question. We have, then, the scapulæ, the hip, and the principle of balance, to take into consideration.

In our army the carriage of the kit and ammunition has always been felt to be a difficulty, and many have been the changes in the infantry knapsacks since the close of the Peninsular war. The method of carriage which was formerly in use, though better than some of the older plans, had grave defects, and it has now been superseded by the new equipment.*

The new infantry equipment, proposed by a War Office Committee, appointed by Lord de Grey in 1864, and of which General Henry Eyre was the president, was devised for the purpose of enabling the infantry soldier to carry his weights with greater comfort (and, therefore, to enable him to march farther), and especially to do away with any chance of injuring his heart and lungs.† This committee have presented four reports to the War Office.‡

Considerable difficulty was found in fixing the best equipment; in addition to all the points already noted, simplicity and durability, and as much freedom from accidental breakage as could be insured, were essential; facility of removal and readjustment for emergencies, adaptation for various conditions of service, and suitableness for military exercises, had all to be considered. After passing in review all the known plans, and experimenting on a large scale, the committee at last recommended a plan which, after an extended trial in many regiments, and being submitted to the opinions of many officers, has been finally authorised and issued in place of the old pattern.

The new equipment is essentially based on the yoke valise plan of the late Colonel Sir Thomas Troubridge, C.B., who had been for many years experimenting on this subject;§ but it is greatly altered in details in order to avoid the use of copper or iron rods. The two great principles are to use the scapulæ and the sacrum in about equal proportion as carriers of the weight, and to place the weights as near to the body as possible, and, as far as could be done, in front as well as behind, so as to avoid the displacement of the centre of gravity. The great advantage of using the sacrum as one of the points of support has been very apparent in the trials of the valise plan. In that way only can the chest be thoroughly relieved; a very great weight can be carried without injury if it is necessary, and apart from that a mechanical advantage of no small moment has been obtained. For the effect of placing the kit and ammunition low down is to free the large muscles of the shoulder and back from the impediment which hinders their action when a knapsack of any kind is carried in its usual place; the bayonet exercise can therefore be much better performed; but more than this, the soldier engaged in a personal struggle is in far better position than with a knapsack on the upper part of the back; for in the latter case, the centre of gravity being displaced (raised and carried backwards), the man has already a tendency to fall back which tells seriously against him. In the new equipment, on the contrary, the great weights being all below the centre of gravity, rather tend to keep a man steadier and firmer on his legs than otherwise.

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* In the former editions descriptions were given of the obsolete Regulation equipment, and of various other plans. But it has been thought unnecessary to repeat these.

† In the chapter on HOME SERVICE are given the facts about the amount of heart and vessel disease in the army. It appears to be very large, and to be attributable, in part at any rate, to exercise under unfavourable conditions. It is not confined to the infantry, but is common to all branches, and perhaps the disease of the vessels is even greater in degree in the cavalry and artillery. My colleague, Professor Maclean, called the attention of the authorities to this matter in a striking lecture delivered at the Royal United Service Institution, and published in the Journal of the Institution, vol. viii., and from which extracts were given in former editions. The army is greatly indebted to Dr Maclean for his clear exposition on this point. The first Report of the Committee on Knapsacks contains the evidence to that date.

‡ Reports of the Committee appointed to inquire into the effect on health of the present system of carrying the Accoutrements, Ammunition, and Kit of Infantry Soldiers.—First Report, 1865; second Report, 1867; third and fourth Reports, 1868.

§ Sir T. Troubridge's equipment will be found described and figured in the 2d edition of this work. I have been informed that he had made experiments on this subject for more than fifteen years.

In order to gain these advantages, and also to lessen the weight of the equipment, the framed knapsack was abandoned, and a bag or valise substituted, which is large enough to carry the service kit and some provisions.

The woodcuts, although not very complete, will give a general notion of this plan, which is indeed not difficult to comprehend, as it is remarkably simple. The total weight of the whole equipment, as intended for active service, is 5 lb 8 oz.

In the first figure the peace equipment is seen. There is a single pouch in front, which can be shifted to one side so as to allow the waist-belt to be opened. The straps running up over the shoulder from the rings are made broad on the scapulæ, they cross on the back like a common pair of braces, [illegible] catching the top of the valise on the other side by a buckle, run [illegible] to the ring on the opposite side from which they started.

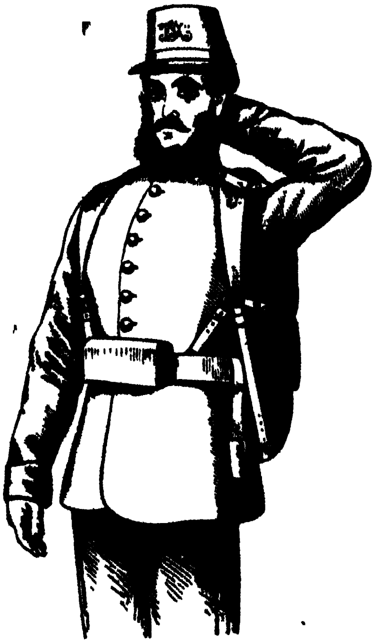

Fig. 110.—No. 1.

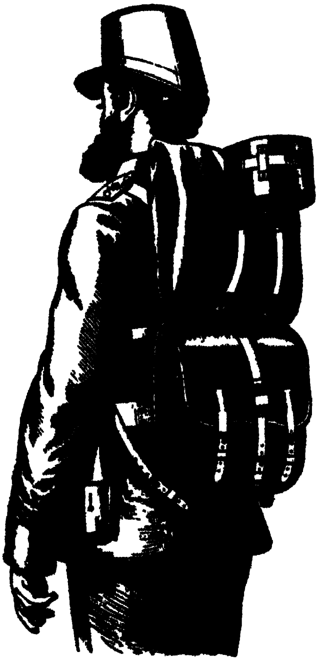

Fig. 111.—No. 2.

From this ring a strap runs to the bottom of the valise which is placed [illegible] on the sacrum, as seen in the second figure; by this arrangement the [illegible] of the valise is thrown partly on the shoulder, partly on the sacrum, and is also thrown forward in a line with the centre of gravity. From the ring another strap runs to the waist-belt and supports the ammunition, which thus balances in part the weight behind.

In full service order two pouches are carried in front, as seen in the third figure, each holding 20 rounds; there is also a ball-bag, intended to hold loose cartridges for rapid firing, in which, if there be necessity, 20 or even 30 cartridges can be put. There is provision in the valise for 20 more.

The greatcoat is placed above the valise, and being soft gives no obstruction to the action of the muscles of the shoulder.

The canteen can be carried as shown in the second figure; but many officers prefer carrying it on the valise, where there are two loops intended for it.

This equipment is very easy, and leaves the chest perfectly free; it is very simple both in principle and construction, and affords many facilities for carriage of articles, such as the haversack, the water-bottle, blanket, &c., which will prove very useful on service. It is of more importance to note here, that it certainly answers all medical requirements; and as it leaves the man very free and unincumbered in his movements, it does away entirely with the stiff unmilitary appearance produced by the old plan.

There seems only one sanitary point which has been urged against this equipment, and that is, that a good deal of the back is covered, and that perspiration collects under the valise. Whatever equipment be used, there must be retention of perspiration under the covered parts; this is inevitable, and is produced by any knapsack. The valise equipment is no exception to the rule, but it is singular how little perspiration really collects under the valise if the man knows how to manage it. By allowing the top of the valise to fall back half-an-inch, a space is left between the greater part of the valise and back, which allows evaporation, and the loins are kept cool. On the march also, when the waist-belt is unbuckled, both the valise and greatcoat hang loosely and away from the body,* and evaporation goes on. I believe that practically there will be found less accumulation of perspiration than with almost any other plan.†

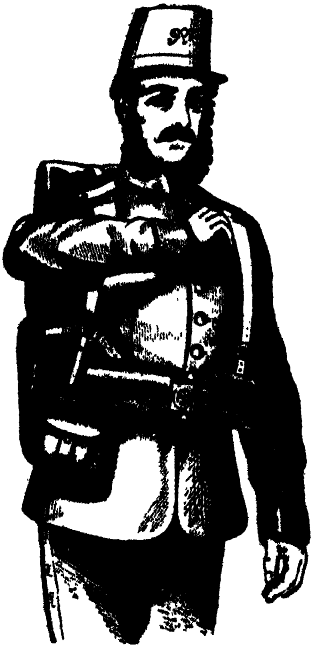

Fig. 112. No. 3.

## SECTION VII.

## WORK OF THE SOLDIER.

The kind and amount of work in the different arms of the service is so different that it is impossible to bring it under one general description. In the artillery, cleaning horses, guns, carriages, and accoutrements, and gun drill; in the cavalry, cleaning of horses, accoutrements, and drill with the special arm; in the infantry, drill, and barrack and fatigue duties, and the cleaning of arms and accoutrements, are all kinds of work, the amount of which is not easy to estimate.

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* The army, who will in time to come, and especially in war, feel the benefit of this arrangement (for though details may be altered, I believe the principal of the valise equipment will be always maintained), should know how much it owes to General Eyre, the President of the War Office Committee on Knapsacks, who laboured at this matter with constant industry and perseverance for years, and left nothing undone to bring the question to a satisfactory end.

† I refer to the 2d edition of this work for figures and descriptions of the continental plans, and to the Reports of the War Office Committee on Knapsacks and Accoutrements, for fuller details than can be given here.

The "Magazine accoutrements," invented by Surgeon-major W. S. Oliver, A.M.D., are now under trial at Aldershott, and have been very favourably reported upon. They appear to be even easier than the valise equipment, and are less complicated in their fittings; they provide for the carriage of more ammunition, and leave the back free for transpiration. There is also a light water-proof cape, which can be used as a sheet or portion of a shelter tent.—(F. de C.)

Much of the work of the artillery and cavalry is highly beneficial to them, and the fine well-developed muscles show that all parts of the body are properly exercised. Some of the work (such as gun drill or sword exercise) is hard, and even violent, and the great amount of aneurism in both bodies of men, as well as in the infantry, has led to the idea that the exercise is either too severe, or is performed under unfavourable conditions, such as heavy equipments or too tight-fitting clothes. Although violent while it lasts, it seems questionable whether the work is so severe as that which many mechanics undergo without injury; it may, however, be more sudden and rapid, and the heart may be brought into more violent action. The conditions under which the work is done are certainly less favourable than in the case of the mechanic, who is never embarrassed by weights or tight clothes.

In the infantry the amount of aneurism is slightly below that of the other arms, but not much so. The hard work in the infantry is the running drill when the weights are carried, bayonet exercise, and long marches; but though severe, it is not so excessive as to lead us to think it would do injury to strong men if all circumstances were favourable.

During war the amount of labour undergone is sometimes excessive, as will be clear from what is said in the next section, and in the rapid campaigns of modern times, very young and weakly men are soon exhausted.

A soldier requires to be trained for the ordeal of active service, and this is now done in our army by a series of gymnastic exercises and systematic marches, intended to develop every muscle, to make the artillery or the cavalry man able to vault on his horse, and the foot soldier to run and to escalade, and to march great distances without fatigue.

*Gymnastic Exercises.*—All military nations have used in their armies a system of athletic exercises. The Greeks commenced such exercises when the increase of cities had given rise to a certain amount of sedentary life. The Romans began to use athletic training in the early days of the Republic, entirely with a view to military efficiency. The exercises were continuous, and were not alternated with periods of complete idleness.

The officers exercised with the men. At a later day, we are told that Marius never missed a single day at the Campus Martius; and Pompey is said by Sallust to have been able at fifty-eight years of age to run, jump, and carry a load as well as the most robust soldier in his army.

Swimming was especially taught by the Romans, and so essential were the gymnastic exercises deemed that, to express that a man was completely ignorant, it was said "he knew neither how to read nor swim." The gymnastic exercises were the last of the old customs which disappeared before the increasing luxury of the latter empire.

In the feudal times the practice of the weapons was the best gymnastic exercise; every peasant in England was obliged to practise with the bow; the noblemen underwent an enormous amount of exercise, both with and without arms, and on foot and horseback.

After the invention of gunpowder the qualities of strength and agility became of less importance for the soldier, and athletic training was discontinued everywhere. But within the last few years the changing conditions of modern warfare have again demanded from the soldier a degree of endurance and of rapidity of movement which the wars of the eighteenth century did not require. And the population generally of this country have of late years become alive to the necessity of compensating, by some artificial system of muscular exercise, the sedentary life which so many lead.

In our own time, the first regular gymnasium appears to have been established at Schwefental, in Saxony, by Saltzmann, with a view of giving health to the body, strengthening certain muscles, and remedying deformities. About forty years ago Ling also commenced in Sweden the system of movements which have made his name so celebrated. Switzerland, Spain, and France followed, and of late years in Germany many gymnastic societies (Turner-Verein) have been founded in almost all the great cities, and the literature of gymnasticism is now a large one. In our own country, the outdoor and vigorous life led by the richer classes, and by many working men, rendered this movement less necessary, but of late years societies have been formed, gymnasia established, and athletic sports encouraged in many places.

Among armies, the Swedish and Prussian were the first to attempt the physical training of their soldiers. France followed in 1845, and ever since a complete system of gymnastic instruction has been carried on in the French army, and a military gymnastic school exists at Vincennes, where instructors for the army are taught.

In the English army this matter attracted less attention until after the Crimean war, when the establishment of gymnasia as a means of training and recreation were among some of the many reforms projected by Lord Herbert. In 1859 General Hamilton and Sir G. Logan, lately Director-General of the Army Medical Department, were sent over to inspect the systems in use on the Continent, and presented a very interesting Report, which was subsequently published. A grant of money was immediately taken for a gymnasium at Aldershot, and this has now been in operation for several years, under the direction of Colonel Hammersley, with most satisfactory results. Gymnasia are now ordered to be built at all the large stations, and a complete code of instructions, drawn up by Mr Maclaren of Oxford, is published by authority.*

The instructions have two great objects—*1st*, To assist the physical development of the recruit; *2d*, To strengthen and render supple the frame of the trained soldier. Every recruit is now ordered to have three months' gymnastic training during (or, if judged expedient by a medical officer, in lieu of part of) his ordinary drill. Two months are given before he commences rifle practice, and one month afterwards. This training is superintended by a medical officer, who will be responsible that it is done properly, and who will have the power to continue the exercises beyond the prescribed time, if he deems it necessary. The exercise for the recruit is to last only one hour a-day, and in addition he will have from two to three hours of ordinary drill.

The trained infantry soldier under ten years' service is ordered to go through a gymnastic course of three months' duration every year, one hour being given every other day. The cavalry soldier is to be taught fencing and sword exercise in lieu of gymnastics.

The Code of Instructions drawn up by Mr Maclaren consists of two parts, elementary and advanced exercises. The exercises have been arranged with very great care, and present a progressive course of the most useful kind. The early exercise commences with walking and running; leaping, with and without the pole, follows; and then the exercises with apparatus commence, the order being the horizontal beam, the vaulting bar, and the vaulting horse: All these are called exercises of progression. The elementary exercises follow, viz., with the parallel bars, the pair of rings, the row of rings, the elastic ladder, the horizontal bar, the bridge ladder, and the ladder plank. Then follow the advanced exercises of climbing on the slanting and vertical pole, the slanting and vertical rope, and the knotted rope.

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* A military system of Gymnastic Exercises, by Archibald Maclaren, Adjutant-General's Office, Horse-Guards, 1862. Mr Maclaren has also published two other works of great utility: a System of Training and Physical Education. This last work should be in the hands of every

Finally, the most advanced exercises consist of escalading, first against a wall, and then against a prepared building.

In the French army swimming and singing are also taught. Both are very useful; the singing is encouraged, not as a matter of amusement (though it is very useful in this way), but as a means of improving the lungs.

Swimming should be considered an essential part of the soldier's education, and it is probable that it will be systematically taught in the English army.

Robert Jackson very strongly recommended that dancing should be taught and encouraged. There is sound sense in this; a spirited dance brings into play many muscles, and in a well-aired room is as good an exercise as can be taken. It would also be an amusement for the men.

### *Duties of the Officer in the Gymnasium.*

The Medical Regulations order the inspecting medical officer and surgeon to visit and advise on the kind and amount of gymnastic exercises. The Queen's Regulations (Para. 1360) order a strict medical examination of each man before the instruction is commenced. During the course further inspections are to be made—of the recruits once a fortnight, of trained soldiers monthly. The measurements of the recruit are also to be taken under the direction of the medical officer. The following points should be attended in regard to—

1. *Recruits.*—The recruit is inspected from time to time, to see if the system agrees with him.

(*a*) *Weight.*—The weight of the body should be ascertained at the beginning and end of the course, and during it, if the recruit in any way complains. With sufficient food recruits almost always gain in weight, therefore any loss of weight should at once call for strict inquiry. It may be the recruit is being overdone, and more rest may be necessary. But in order to avoid the greatest error, the weights must be carefully taken; if they are taken at all times of the day, without regard to food, exercise, &c., accuracy is impossible; there may be 2 ℔ or 3 ℔ variation. The physiological practice during experiments is to take the weight the first thing in the morning before breakfast, and after emptying the bladder. If it cannot be done at this time, scarcely any reliance can be placed on the result. Food alone may raise the weight 2 ℔ or 3 ℔, and we cannot be sure that the same quantity of food is taken daily. The clothes, also, must be remembered; men should be weighed naked if possible, if not, in their trousers only, and always in the same dress.

(*b*) *Height.*—This is usually taken in the erect position. Dr Aitken* recommends it to be taken when the body is stretched on a horizontal plane. A series of experiments on both plans would be very desirable.

(*c*) *Girth of Chest.*—The chest is measured to ascertain its absolute size, and its amount of expansion.

It is best measured when the man stands at attention, with the arms hanging; and the tape should pass round the nipple line. The double tape (the junction being placed on the spine) is a great improvement over the single tape, as it measures the sides separately, and with practice can be done as quickly.

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* On the growth of the Recruit, p. 68.

The chest should be measured in the fullest expiration and fullest inspiration. If the chest is measured with the arms extended, or over the head, as ordered in the Regulations in Recruiting, the scapulæ may throw out the tape from the side of the chest.

(*d*) *The Inspiratory Power*, as expressed by the spirometer, may also be employed.

(*e*) *Growth of Muscles.*—This is known by feeling the muscles when relaxed and in action, and by measurements. The measurement of the upper arm should be taken either when the arm is bent over the most prominent part of the biceps, or over the thickest part when the arm is extended.

(*f*) *General Condition of Health.*—Digestion, sleep, complexion, &c. The recruit should also be inspected during the time of exercise, to watch the effect on his heart, lungs, and muscles. In commencing training the great point is to educate, so to speak, the heart and lungs to perform suddenly, without injury, a great amount of work. To do this there is nothing better than practice in running and jumping. It is astonishing what effect this soon has. If possible, the increase in the number of respirations after running 200 or 300 yards should be noted on the first day, as this gives a standard by which to judge of the subsequent improvement. But as it would be impossible and a waste of time to do this with all the men, directly the run is ended the men should range in line, and the medical officer should pass rapidly down and pick out the men whose respiration is most hurried. In all the exercises the least difficulty of respiration should cause the exercise to be suspended for four or five minutes.* The heart should be watched; the characters indicating the necessity for rest or easier work are excessive rapidity (130–160), smallness, inequality, and irregularity.

Soreness of muscles after the exercise, or great weariness, should be inquired into. It would be well every now and then to try the inguinal and femoral rings during exertion and coughing.

One very important part in gymnastic training depends on the instructor. A good instructor varies the work constantly, and never urges a man to undue or repeated exertion. If the particular exercise cannot be done by any man it should be left for the time. Anything like urging or jeering by the rest of the men should be strictly discountenanced. The instructor should pass rapidly from exercise to exercise, so that a great variety of muscles may be brought into play for a short time each, and as the men work in classes, and all cannot be acting at once, there is necessarily a good deal of rest.

The grand rule for an instructor is, then, change of work and sufficient rest.

In the case of a recruit who has not been used to much physical exertion the greatest care must be taken to give plenty of rest during the exercises. There may even seem to be an undue proportion of rest for the first fortnight, but it is really not lost time. The medical officer is only directed to visit the gymnasium once a fortnight, but during the first fortnight of the training of a batch of recruits he should visit it every day.

With proper care men are very seldom injured in gymnasia. I was informed at Vincennes that, though they did not take men unless they were certified as fit by a medical officer, they occasionally got men with "delicate chests," though not absolutely diseased. These men always improved marvellously during the six months they remained at Vincennes. In fact, a regulated course of gymnastics is well known to be an important remedial measure in threatened phthisis. Hernia is never caused at Vincennes. Nor does it appear that any age is too great to be benefited by gymnastics, though in old men the condition of the heart and vessels (as to rigidity) should be looked to.

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* In the training of horses the points always attended to are—the very gradual increase of the exercise; gentle walking is persevered in for a long time, then slow gallops; then, as the horse gains wind and strength, quicker gallops: but the horse is never distressed, and a boy would be dismissed from a stable if it were known that the horse he was riding showed, by sighing, or in any other way, that the speed was too great for him.

*Trained Soldiers.*—There is less occasion for care with these men; they should, however, be examined from time to time, and any great hurry of respiration noted. The man should be called out from the class, his heart examined, and some relaxation advised if necessary.

### *Drills and Marches.*

In drill, and during marches, the movements of the soldiers are to a certain extent constrained. In the attitude of "attention" the heels are close together, the toes turned out at an angle of 60°, the arms hang close by the sides, the thumbs close to the forefingers, and on a line with the seam of the trousers. The position is not a secure one, as the basis of support is small, and in the manual and platoon exercise the constant shifting of the weight changes the centre of gravity every moment, so that constant muscular action is necessary to maintain the equilibrium. Men are therefore seldom kept long under attention, but are told to "stand at ease" and "stand easy," in which cases, and especially in the latter, the feet are farther apart and the muscles are less constrained.

In marching the attitude is still stiff—it is the position of attention, as it were, put into motion. The slight lateral movement which the easy walker makes when he brings the centre of gravity alternately over each foot, and the slight rotatory motion which the trunk makes on the hip-joint, is restrained as far as it can be, though it cannot be altogether avoided, as is proved by observing the light swaying motion of a line of even very steady men marching at quick time. Marching is certainly much more fatiguing than free walking; and in the French army, and by many commanding officers in our own, the men are allowed to walk easily and disconnectedly, except when closed up for any special purpose. This may not look so striking to the eye of a novice, but to the real soldier, whose object is at the end of a long march to have his men so fresh that, if necessary, they could go at once into action, such easy marching is seen to be really more soldier-like than the constrained attitudes which lead so much sooner to the loss of the soldier's strength and activity.

In walking, the heel touches the ground first, and then rapidly the rest of the foot, and the great toe leaves the ground last. The soldier, in some countries, is taught to place the foot almost flat on the ground, but this is a mistake, as the body loses in part the advantage of the buffer-like mechanism of the heel. The toes are turned out at an angle of about 30° to 45°, and at each step the leg advances forward and a little outward; the centre of gravity, which is between the navel and the pubis, about in a line with the promontory of the sacrum (Weber), is constantly shifting. It has been supposed that it would be of advantage to keep the foot quite straight, or to turn the toes a little in, and to let the feet advance almost in a line with each other. But the advantage of keeping the feet apart and the toes turned out, is that, first, the feet can advance in a straight line, which is obviously the action of the great *vasti* muscles in front of the thigh; and, second, when the body is brought over the foot, the turned-out toes give a much broader base of support than when the foot is straight. The spring from the great toe may perhaps be a little greater when the foot is straight (though of this I am not certain, and I do not see why the gastrocnemii and solei should contract better in this position), but there is a loss of spring from the other toes. Besides this, it has been shown by Weber that when the leg is at its greatest length, *i.e.*, when it has just urged the body forward, and is lifted from the ground, it falls forward like a pendulum from its own weight, not from muscular action, and this advance is from within and behind to without and before, so that this action alone carries the leg outwards.

The foot should be raised from the ground only so far as is necessary to clear obstacles. Formerly, in the Russian Imperial Guard, the men were taught to march with a peculiar high step, the knee being lifted almost to a level with the acetabulum. The effect was striking, but the waste of power was so great that long marches were impossible, and I believe this kind of marching is now given up. The foot should never be advanced beyond the place where it is to be put down; to do so is a waste of labour.

In the English army the order is as follows:—

*Length and Number of Steps in Marching.*

| Kind of Step. | Length. | No. per Minute. | Ground Traversed per Minute. | Ground Traversed per Hour without Halts. |
|---|---|---|---|---|
| | Inches. | | Feet. | Miles. |
| Slow time, . . | 30 | 75 | 187½ | 2·1 |
| Quick time, . . | 30 | 116 | 290 | 3·3 |
| Stepping out, . | 33 | 110 | 302½ | 3·4 |
| Double, . . | 33 | 165 | 453¾ | 5·157 |
| Stepping short, . | 21 | ... | ... | ... |
| Side step, . . | 12 | ... | ... | ... |
| or when | | | | |
| Forming four deep, | 24 | ... | .. | ... |
| Stepping back, . | 30 | ... | ... | ... |

The "double" is never continued very long; it is stopped at the option of the commanding officer. In the French army it is ordered not to be continued longer than twenty minutes.* At the double (if without arms), the forearms are held horizontally, the elbows close to the side; if the rifle is carried, one arm is so held. There is an advantage in this attitude, as the arms are brought into the position of least resistance; more fixed points are given for the muscles of respiration, and the movement of the arms and shoulders facilitates the rapid shifting of the centre of gravity.

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* It may be worth while to mention some of the feats of celebrated pedestrians as a means of comparison.

The mile has been walked in 7 minutes (or at the rate of 8½ miles per hour). Such an exertion is enormous, for the exertion is in the ratio of the velocity.

Ten miles have been walked by Captain Saunders in 93½ minutes, and 21 miles in 3 hours by Westhall.

In running, 100 yards have been covered in 9½ seconds; a little over 10 sec. is the usual time.

| | | |
|---|---|---|
| ½ mile in | | 1 minute 58 seconds. |
| 1 mile in | | 4 minutes 22¼ " |
| 2 miles in | | 9 minutes 20 " |
| 6 " | | 31 " |
| 10 " | | 51 " |
| 11 " | and 46 yards | 60 " |
| 20 " | | 120 " |
| 40 " | | 5 hours. |
| 100 " | | 18 hours and 50 minutes. |

O'Leary and Weston covered 500 miles in 144 hours; Gale walked 1500 in 1000 consecutive hours, and 4000 quarter miles in 4000 successive periods of 10 minutes each,—both enormous feats of endurance.

Quick time is always used in drills and marching. The ground got over per hour is generally reduced by halts to 2·8 miles.

Running drill has been introduced during the last seven years; it is not carried beyond 1000 yards, and the men are gradually brought up to this amount. The pace is not to exceed 6 miles an hour. All men over 15 years' service and weakly men (if considered unfit by the medical officers), are to be excused (Queen's Reg. 1377).

In the French army the length of the step is rather different.

*French Steps in English Measures.* (*Morache*, 1874).

| | Length of Step in inches. | Steps per Minute. | Ground Traversed per Minute in Feet. | Ground Traversed per Hour in Miles. |
|---|---|---|---|---|
| Pas ordinaire, . | 26 | 76 | 164 | 1·86 |
| Pas de route, . | 26 | 90 | 195 | 2·22 |
| Pas accéléré, . | 26 | 110 | 238 | 2·70 |
| Pas de charge, . | 29·5 | 120 | 295 | 3·35 |
| Pas maximum (gymnastique), | 32·5 | 165 | 449 | 5·10 |

The French step is therefore 4 inches shorter than the English; this is perhaps because the men are, as a rule, shorter. The Prussian and the Bavarian step is 31½ inches long, and 112 steps are taken per minute.

The exact length of the step, and the number per minute, are very important questions. The object of the soldier is to get the step as long, and the number per minute as great, as possible, without undue fatigue, so as to get over the greatest amount of ground.

The quickest movement of the leg forward in walking has been shown by Weber to correspond very closely with half a pendulum vibration of the leg, and to occupy on an average, 0·357 seconds; this would give 168 steps per minute, supposing the one foot left the ground when the other touched it. This is much quicker than the army walking step (the double is a run), and no doubt much quicker than could long be borne, since, with a step of only 30 inches, it would give nearly 5 miles per hour; but it may be a question whether, with men in good condition, the pace might not be increased to 130 per minute. Practical trials, however, with soldiers carrying arms and accoutrements can only decide this point.

The length of the step of an average man has been fixed by the Brothers Weber at about 28 inches. In individual cases, it depends entirely on the length of the legs. Robert Jackson considered 30 inches as too long a step for the average soldier, and suggested 27 inches. It is of great importance not to lessen the length too much, and it would be very desirable to have some well-conducted experiments on this point. The steps must be shorter if weights are carried than without them; a little consideration shows how this is: When a man walks, he lifts his whole body and propels it forward, and in doing so, the point of centre of gravity describes a circular motion, in the form of an arc about the foot. The less the body is raised, or, in other words, the shorter the versed sine of the arc, the less of course the labour. In long steps the arc, and of course the versed sine, or height to which the body is raised, are greater; in short steps, less.[*] It is probable that, with the weight the soldier carries (60 lb), the step of 30 inches is quite long enough, perhaps even too long; and it would be desirable to know if, after a march of six or eight miles, the steps do not get shorter.

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[*] The Brothers Weber, however, have shown that the angle at which the body is bent and, consequently, the coefficient of resistance are not affected by the length of step, provided the velocity remains the same.

In the French army, the march is commenced at the *pas de route* (90 steps per minute); then accelerated to 110 steps; during the last half-hour 100 steps are returned to. But the soldiers themselves often set the step; the grenadiers and the voltigeurs alternately leading. Four kilometres (= 2½ miles) are done in forty-five or forty-eight minutes. One kilometre (= 0·62 miles) is done in about twelve minutes.

The soldier, in this country, when he marches in time of peace in heavy order, carries his pack, kit, haversack, water-bottle, greatcoat, rifle, and ammunition (probably twenty rounds). In India, he does not carry his pack or greatcoat.

There is a very general impression that the best marchers are men of middle size, and that very tall men do not march so well.

*Length of the March.*—In "marching out" in time of peace, which is done once or twice a-week in the winter, the distance is 6 or 8 miles. In marching on the route or in war, the distance is from 10 or 12 miles to occasionally 18 or 20, but that is a long march. A forced march is any distance—25 to 30, and occasionally even 40 miles being got over in twenty-four hours. In the Prussian army the usual march is 14 miles (English); if the march is continuous, there is a halt every fourth day.

*Conditions rendering Marches Slower.*—The larger the body of men the slower the march; 14 miles will be done in six or seven hours by two or three regiments, but not under eight or nine hours by 8000 or 10,000 men. A large army will not go over 14 miles under ten hours usually. A single regiment can do 20 miles in eight hours, but a large army will take twelve or fourteen, including halts. Head winds greatly delay marches; a very strong wind acting on a body of men will cause a difference of 20 to 25 per cent., or 4 miles will be got over instead of 5.

Snow and rain, without head wind, delay about 10 to 15 per cent., or 4½ miles are done instead of 5.

Of course, bad or slippery roads, deep sands, heavy snows, jungle and brushwood, are often acting against the soldier, and in hilly and jungly countries only 5 or 6 miles may be got over in a day.

*Conditions adding to the Fatigue of Marching.*—Heat—dust—thirst—constant halts from obstructions—want of food—bad weather, especially head winds with rain. In order to avoid heat and dust, it is desirable, when it can be done, to separate the cavalry and artillery from the infantry; to let the latter march in open order, and with as large a front as possible.

*Instances of Marches during War.*—It is most important for a soldier to know what has been done and what can be done with a large body of foot soldiers, and it is scarcely less interesting to the physiologist. In comparing the marches of infantry, it must always be remembered how great an effect increasing the number of men has in lessening the rapidity and length of a march, and in increasing the fatigue. No large army has ever made the marches small bodies of troops have done.

At times the fatigue undergone by trained men has been something almost incredible. Wolfe mentions in one of his letters that in 1760, just before the battle of Dettingen, his regiment marched from Frankfort "two days and two nights with only nine or ten hours' halt." This would be a march then, of thirty-eight hours out of forty-eight. He gives the distance at about 40 miles, but it was probably more. The 43d, 52d, and 95th Regiments of Foot, forming the Light Division under Crawfurd, made a forced march in July 1809, in Spain, in order to reinforce Sir Arthur Wellesley at the battle of Talavera. About fifty weakly men were left behind, and the brigade then marched 62 miles in twenty-six hours, carrying arms, ammunition, and pack—

in all, a weight of between 50 lb and 60 lb.* There were only seventeen stragglers. The men had been well trained in marching during the previous month.

One of these regiments—the 52d—made in India, in 1857, a march as extraordinary. In the height of the mutiny, intelligence reached them of the locality of the rebels from Sealkote. The 52d, and some artillery, started at night on the 10th of July 1857 from Umritsur, and reached Goodasepore, 42 miles off, in twenty hours, some part of the march being in the sun. On the following morning they marched 10 miles, and engaged the mutineers. They were for the first time clad in the comfortable gray or dust-coloured native Khakee cloth.

A march of a small party of French was narrated by an officer of the party who was afterwards wounded at Sedan, to Dr Frank, who kindly gave me the particulars. A company of a regiment of Chasseurs of Macmahon's army, after being on grand guard, without shelter or fire, during the rainy night of the 5th–6th August 1870, started at three in the morning to rejoin its regiment in retreat on Niederbronn, after the battle of Weissenburg. It arrived at this village at 3.30 in the afternoon, and started again for Phalsbourg at six o'clock. The road was across the hills, and along forest tracts, which were very difficult for troops. It arrived at Phalsbourg at 8.30 o'clock in the evening of the next day. The men had, therefore, marched part of the night of the 5th–6th August, the day of the 6th, the night of the 6th–7th, and the day of the 7th till 8.30 P.M. The halts were eight minutes every hour, from 3.30 to 6, one hour in the night of the 6th–7th, and 2½ hours on the 7th. Altogether, including the halts, the march lasted 41½ hours, and the men must have been actually on their feet about thirty hours, in addition to the guard duty on the night before the march.

An officer of a Saxon Fusilier regiment gave me the following statement of a forced march in one of the actions at Metz, in 1870. The regiment was alarmed at midnight and marched at one A.M., and continued marching with halts until 7 P.M.; they bivouacked for the night, marched at 7 the next morning, came into action at 1·30, and in the evening found themselves 15 kilometres beyond the field of battle. The total distance was 53½ miles in about forty-two hours, with probably fifteen hours' halt.

Roth mentions that the 18th division of the Saxon army in the various manœuvres about Orleans marched, on the 16th and 17th December 1870, 54 English miles.

Von der Tann's Bavarian army, in retreat on Orleans, marched 42 miles in twenty-six hours.

These were all forced marches for the purpose of coming into action or retiring after discomfiture. Apart from the Peninsular Light Division march, they show that in two days and one night a small body of men may cover 54 English miles, and that is probably near the limit of endurance. The Light Division march is so excessive (62 miles in twenty-six hours, or 2·38 miles every hour, without reckoning halts), that it may be doubted if the distance was properly reckoned.†

When a large army moves it has never accomplished such distances.

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* Napier's War in the Peninsula, 3d edit. vol. ii. p. 400; Moorsom's Record of the 52d Regiment, p. 115. Both authors state that the men carried between 50 lb and 60 lb on this extraordinary march, but there seems a little doubt of this. During the Peninsular war the men carried bags, weighing about 2 lb, and not framed packs, and their kits were very scanty. Lord Clyde, in talking of this march to my colleague, Mr Longmore, told him the men only carried a shirt, and a spare pair of either boots or soles. He saw the men march in. In all probability also they would not carry their full ammunition.

† Sir William Cope, who was one of the officers of the 95th, says (in his History of the Rifle Brigade, formerly the 95th), that the distance was only 40 miles.

In 1806 the French army marched on one occasion 49 kilometres, or 30½ miles. On the 15th June 1815, Napoleon made a forced march to surprise the Prussians and English, but only accomplished 30 kilometres or 18¾ miles.

In Sherman's celebrated march across the Southern States the daily distance was about 14 miles. When the Prussians advanced on Vienna, after the battle of Königgrätz in 1866, they accomplished almost the same, and had also outpost duty every other night.

The Russians marched in the expedition to Khiva, in 1873, 468·7 miles (English) in 89 days, but as actual marching was done only on 44 days, the average daily march was (468·7 ÷ 44) 10·65 miles; the longest march was 26¼ miles.*

Macmahon's army, in its march to relieve Bazaine at Metz, could only accomplish about 10 miles daily, while the Crown Prince of Prussia in pursuit was far more rapid.

After Sedan, the Prussian and Saxon troops pushed on to Paris by forced marches and accomplished on an average 35 kilometres, or 21¾ miles, daily, and they marched on some days 42 to 45 kilometres (26 to 28 miles); they started at five or six, and were on their ground from four to eight o'clock, the average pace being 5 kilometres (3·1 miles) per hour.

In the Indian mutiny several regiments marched 30 miles a day for several days.

When marches are continued day after day, an average of about 20 miles may be expected from men for two or three weeks, after which, probably, the amount would lessen.

It is difficult to estimate the labour of such marches, as besides the actual march there is often work in fetching water, cooking, pitching tents, sentry, outpost, and picket duty, &c. As 20 miles a-day with 60 ℔ weight is equivalent to lifting 495 tons one foot, and there is always additional work to be done, it is clear that the labour is excessive and must be prepared for, and that during the time the men must be well fed.

In marching long distances, the extent of the marches, the halting grounds, &c., are fixed by the Quartermaster-General's department.

Occasionally the march has been divided, one part being done in the early morning, and the remainder late in the afternoon. It is, however, better to make the march continuous, and, if necessary, to lengthen the mid-day halt.

*Order of March.*—Whenever possible, it seems desirable to march in open order. Inspector-General J. R. Taylor has given evidence to show that a close order of ranks is a cause of unhealthiness in marching, similar to that of overcrowding in barracks; and the Medical Board of Bengal have, in accordance with this opinion, recommended that military movements in close order should be as little practised as possible. There should also be as much interval as can be allowed between bodies of troops.

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* In 1709, on the 3d Sept., in order to secure the passage of the Haine, the Prince of Hesse Cassel made a march of 49 English miles in 56 successive hours, with 4000 foot and 60 squadrons (Coxe's Life of Marlborough v. 10–21).

Alison (History of Marlborough, vol. ii. p. 27), says that "this rapidity of advance for such a distance had never been previously surpassed, though it has been out-done in later times." He refers in a foot-note to Mackenzie's march to join Wellington at Talavera, which he gives as 62 English miles in 26 hours; also the Russian foot guards advancing to Paris in 1814, after the combat at Fère-Champenoise, marched 48 miles in 26 hours.

In the Times of 1873 a writer gives the following statement; he quotes from a dispatch published in the London Gazette of 1859. "During the day the troops from Khulkhulla marched 35 miles, and those from the camp 48 miles, and much of this under a more than usually hot sun." He also says that at the end of 1858, General Whitlock marched 85 miles in 37 hours to relieve Kirwee.

In April 1859 Colonel Deaalis, (London Gazette 1859), reported a march of not less than 40 miles. Captain Rennie's force also marched 40 in 24 hours. In the same No. of the Times, Captain [illegible] states that Daly's Guide Corps marched from near Peshawur to Delhi, 580 miles in 22 days. Sir Hope Grant says 750 miles in 28 days. He also says that the 1st Bengal Fusiliers (European) marched 65 miles in 36 hours.

*Effects of Marches.*—Under ordinary conditions, both in cold and hot countries, men are healthy on the march.

But marches are sometimes hurtful—

*1st*, When a single long and heavy march is undertaken when the men are overloaded, without food, and perhaps without water. The men fall out, and the road becomes strewed with stragglers. Sometimes the loss of life has been great.

The prevention of these catastrophes is easy. Place the soldier as much as possible in the position of the professional pedestrian; let his clothes and accoutrements be adapted to his work; supply him with water and proper food, and exclude spirits; if unusual or rapid exertion is demanded, the weights must be still more lightened.

When a soldier falls out on the march he will be found partially fainting, with cold moist extremities, a profuse sweat everywhere; the pulse is very quick and weak—often irregular; the respiration often sighing. The weights should be removed, clothes loosened, the man laid on the ground, cold water dashed on the face, and water given to drink in small quantities. If the syncope is very alarming, brandy must be used as the only way of keeping the heart acting, but a large quantity is dangerous. If it can be obtained, weak hot brandy and water is the best under these circumstances. When he has recovered, the man must not march—he should be carried in a waggon, and in a few minutes have something to eat, but not much at a time. Concentrated beef-tea mixed with wine is a powerful restorative, just as it is to wounded men on the field.

*2d*. When the marches which singly are not too long, are prolonged over many days or weeks without due rest.

With proper halts men will march easily from 500 to 1000 miles, or even farther, or from 12 to 16 miles per diem, and be all the better for it; but after the second or third week's, there must be one halt in the week besides Sunday. If not, the work begins to tell on the men; they get out of condition, the muscles get soft, appetite declines, and there may be even a little anæmia. The same effects are produced with a much less quantity of work, if the food is insufficient. Bad food and insufficient rest are then the great causes of this condition of body.

In such a state of body malarious fevers are intensified, and in India attacks of cholera are more frequent. It has been supposed that the body is overladen with the products of metamorphosis, which cannot be oxidised fast enough to be removed.

Directly the least trace of loss of condition begins to be perceived in the more weakly men (who are the tests in this case), the surgeon should advise the additional halt, if military exigencies permit. On the halt day the men should wash themselves and their clothes, and parade, but should not drill.

*3d*. When special circumstances produce diseases.

Exposure to wet and cold in temperate climates is the great foe of the soldier. As long as he is marching, no great harm results; and if at night he can have dry and warm lodgings, he can bear, when seasoned, great exposure. But if he is exposed at night as well as day, and in war he often is so, and never gets dry, the hardiest men will suffer. Affections arising from cold, such as catarrhs, rheumatism, pulmonary inflammation, and dysentery are caused.

These are incidental to the soldier's life, and can never be altogether avoided. But one great boon can be given to him; a waterproof sheet, which can cover him both day and night, has been found the greatest comfort by those who have tried it.

The soldier may have to march through malarious regions. The march should then be at mid-day in cold regions, in the afternoon in hot. The early morning marches of the tropics should be given up for the time; the deadliest time for the malaria is at and soon after sunrise. If a specially deadly narrow district has to be got through, such as a Terai, at the foot of hills, a single long march should be ordered; a thoroughly good meal, with wine, should be taken before starting, and if it can be done, a dose of quinine. If the troops must halt a night in such a district, every man should take five grains of quinine. Tents should be pitched in accordance with the rules laid down in the chapter on CAMPS, and the men should not leave them till the sun is well up in the heavens.

Yellow fever or cholera may break out. The rules in both cases are the same. At once leave the line of march; take a short march at right angles to the wind; separate the sick men, and place the hospital tent to leeward; let every evacuation and vomited matter be at once buried and covered with earth, and employ natives (if in India) to do this constantly, with a serjeant to superintend. Let every duty-man who goes twice to the rear in six hours report himself, and, if the disease be cholera, distribute pills of acetate of lead and opium to all the non-commissioned officers. Directly a man who becomes choleraic has used a latrine, either abandon it, or cover it with earth and lime if it can be procured. If there is carbolic acid or chloride of zinc, or lime or sulphate of iron or zinc at hand, add some to every stool or vomit.

In two days, whether the cholera has stopped or not, move two miles; take care in the old camp to cover everything, so that it may not prove a focus of disease for others. The drinking water should be constantly looked to. A regiment should never follow one which carries cholera; it should avoid towns where cholera prevails; if it itself carries cholera, the men should not be allowed to enter towns. I know one instance (and many are known in India) where cholera was in this way introduced into a town.

The men may suffer from insolation. This will generally be under three conditions.[*] Excessive solar heat in men unaccustomed to it and wrongly dressed, as in the case of the 98th in the first China war, when the men having just landed from a six months' voyage, and being buttoned up and wearing stocks, fell in numbers during the first short march. A friend who followed with the rearguard informed me that the men fell on their faces as if struck by lightning; on running up and turning them over, he found many of them already dead. They had, no doubt, struggled on to the last moment. This seems to be intense asphyxia, with sudden failure of the heart-action, and is the "cardiac variety" of Morehead.

A dress to allow perfectly free respiration (freedom from pressure on chest and neck), and protection of the head and spine from the sun, will generally prevent this form. The head-dress may be wetted from time to time; a piece of wet paper in the crown of the cap is useful. When the attack has occurred, cold effusion, artificial respiration, ammonia, and hot brandy and water to act on the heart, seem the best measures. Bleeding is hurtful; perhaps fatal. Cold affusion must not be pushed to excess.

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[*] Of course I do not enter here into the pathology of this affection. For this I refer to the great works of Morehead and Martin and Aitken and Maclean. I look at it from a special point of view.

In a second form the men are exposed to continued heat,* both in the sun and out of it, day and night, and the atmosphere is still, and perhaps moist, so that evaporation is lessened, or the air is vitiated. If much exertion is taken, the freest perspiration is then necessary to keep down the heat of the body; if anything checks this, and the skin gets dry, a certain amount of pyrexia occurs; the pulse rises; the head aches; the eyes get congested; there is a frequent desire to micturate (Longmore), and gradual or sudden coma, with perhaps convulsions and stertor, comes on, even sometimes when a man is lying quiet in his tent. The causes of the interruption to perspiration are not known; it may be that the skin is acted upon in some way by the heat, and from being over-stimulated, at last becomes inactive.

In this form cold affusion, ice to the head, and ice taken by the mouth, are the best remedies; perhaps even ice water by the rectum might be tried. Stimulants are hurtful. The exact pathology of this form of insolation is uncertain. It is the cerebro-spinal variety of Morehead.

In a third form a man is exposed to a hot land-wind; perhaps, as many have been, from lying drunk without cover. When brought in, there is generally complete coma with dilated pupils, and a very darkly flushed face. After death the most striking point is the enormous congestion of the lungs, which is also marked, though less so, in the other varieties. Although I have dissected men in a very large number of diseases both in India and England, I have never seen anything like the enormous congestion I have observed in two or three cases of this kind.

As prevention of all forms, the following points should be attended to:—Suitable clothing; plenty of cold drinking water (Crawford); ventilation: production in buildings of currents of air; bathing; avoidance of spirits; lessening of exertion demanded from the men.

### *Duty of Medical Officers during Marches.*

*General Duties on Marches in India or the Colonies.*—Before commencing the march, order all men with sore feet to report themselves. See that all the men have their proper kits, neither more nor less. Every man should be provided with a water-bottle to hold not less than a pint. Inspect halting-grounds, if possible; see that they are perfectly clean, and that everything is ready for the men. In India, on some of the trunk roads there are regular halting-grounds set apart. The conservancy of these should be very carefully looked to, else they become nothing but foci for disseminating disease. If there are no such places, halting-grounds are selected. It should be a rule never to occupy an encamping ground previously used by another corps if it can be avoided; this applies to all cases. Select a position to windward of such an old camp, and keep as far as possible from it. The encampment of the transport department, elephants, camels, bullock carts, &c., must be looked to,—they often are very dirty: keep them to leeward of the camp, not too near, and see especially that there is no chance of their contaminating streams supplying drinking water. If the encampment is on the banks of a stream, the proper place for the native camp and bazaar will always be lower down the stream. The junior medical officer, if he can be spared, should be sent forward for this purpose with a combatant officer. Advise on length of marches, halts, &c., and draw up a set of plain rules to be promulgated by the commanding officer, directing the men how to manage on the march if exposed to great heat or cold, or to long-continued exertion, how to purify water, clean their clothes, &c. If the march is to last some time, and if halts are made for two or three days at a time, write a set of instructions for ventilating and cleaning tents, regulation of latrines, &c.

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* The heat of sandy plains is the worst, probably, from the great absorption of heat and the continued radiation. The heat of the sun, *per se*, is not so bad; on board ship sun-stroke is uncommon.

*Special Duties for the March itself.*—Inspect the breakfast or morning refreshment; see that the men get their coffee, &c. On no account allow a morning dram, either in malarious regions or elsewhere. Inspect the water-casks, and see them properly placed, so that the men may be supplied; inspect some of the men, to see that the water-bottles are full. March in rear of the regiment so as to pick up all the men that fall out, and order men who cannot march to be carried in waggons, dhoolies, &c., or to be relieved of their packs, &c. If there are two medical officers, the senior should be in rear; if a regiment marches in divisions, the senior is ordered to be with the last. When men are ordered either to be carried or to have their packs carried, tickets should be given specifying the length of time they are to be carried. These tickets should be prepared before the march, so that nothing has to be done but to fill in the man's name, and the length he is to be carried.

Special orders should be given that, at the halt, or at the end of the day's march, the heated men should not uncover themselves. They should take off their pack and belts, but keep on the clothes, and, if very hot, should put on their greatcoats. The reason of this (viz., the great danger of chill *after* exertion) should be explained to them. In an hour after the end of the march the men should change their underclothing, and hang the wet things up to dry; when dry they should be shaken well, and put by for the following day. Some officers, however, prefer that their men should at once change their clothes and put on dry things. This is certainly more comfortable. But, at any rate, exposure must be prevented.

It will be found that old soldiers eat very little while on the march; the largest meal is taken at the end.

At the end of the march inspect the footsore men. Footsoreness is generally a great trouble, and frequently arises from faulty boots, undue pressure, chafing, riding of the toes from narrow soles, &c. Rubbing the feet with tallow, or oil or fat of any kind,* before marching, is a common remedy. In the late war the Germans found tannin very useful,—they used an ointment of one part of tannin to twenty parts of zinc ointment. A good plan is to dip the feet in very hot water, before starting, for a minute or two; wipe them quite dry, then rub them with soap (soft soap is the best), till there is a lather; then put on the stocking. At the end of the day, if the feet are sore, they should be wiped with a wet cloth, and rubbed with tallow and spirits mixed in the palm of the hand (Galton). Pedestrians frequently use hot salt and water at night, and add a little alum. Sometimes the soreness is owing simply to a bad stocking; this is easily remedied. Stockings should be frequently washed; then greased. Some of the German troops use no stockings, but rags folded smooth over the feet. This is a very good plan. Very often soreness is owing to neglected corns, bunions, or in-growing nails, and the surgeon must not despise the little surgery necessary to remedy these things; nothing, in fact, can be called little if it conduces to efficiency. As shoes are often to blame for sore feet, it becomes a question whether it might not be well to accustom the soldier to do without shoes.

Frequently men fall out on the march to empty the bowels; the frequency with which men thus lagging behind the column were cut off by Arabs, led the French in Algeria to introduce the slit in the Zouave trousers, which require no unbuckling at the waist, and take no time for adjustment.

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* An old prejudice gives the preference to stag's fat, but there is little doubt all oils are equally effectual.

At the long halt, if there is plenty of water, the shoes and stockings should be taken off, and the feet well washed; even wiping with a wet towel is very refreshing. The feet should always be washed at the end of the march.

Occasionally men are much annoyed with chafing between the nates or inside of the thighs. Sometimes this is simply owing to the clothes, but sometimes to the actual chafing of the parts. Powders are said to be the best—flour, oxide of zinc, and above all, it is said, fuller's earth.

*If blisters form on the feet, the men should be directed not to open them during the march, but at the end of the time to draw a needle and thread through; the fluid gradually oozes out.*

*All footsore men should be ordered to report themselves at once.*

*Sprains are best treated with rags dipped in cold water, or cold spirit and water with nitre, and bound tolerably tight round the part. Rest is often impossible. Hot fomentations, when procurable, will relieve pain.**

Marches, especially if hurried, sometimes lead men to neglect their bowels, and some trouble occurs in this way. As a rule, it is desirable to avoid purgative medicines on the line of march, but this cannot always be done; they should, however, be as mild as possible.

Robert Jackson strongly advised the use of vinegar and water as a refreshing beverage, having probably taken this idea from the Romans, who made vinegar one of the necessaries of the soldier. It was probably used by them as an anti-scorbutic; whether it is very refreshing to a fatigued man, I do not know.

There is only one occasion when spirits should be issued on the march: this is on forced marches, near the end of the time, when the exhaustion is great. A little spirit, in a large quantity of hot water, may then be useful, but it should only be used on great emergency. Warm beer or tea is also good; the warmth seems an important point. Ranald Martin tells us that in the most severe work in Burmah, in the hot months of April and May, and in the hot hours of the day, warm tea was the most refreshing beverage. This I found also from my own experience. Several friends have told me that both in India, and in bush travelling in Australia, there was nothing so reviving as warm tea. Chevers mentions that the juice of the country onion is useful in lessening thirst during marches in India, and that, in cases of sun-stroke, the natives use the juice of the unripe mangoe mixed with salt.

Music on the march is very invigorating to tired men. Singing should also be encouraged as much as possible.

*Marching in India.*—Marches take place in the cool season (November to February), and not in the hot or rainy seasons, except on emergency; yet marches have been made in hot weather without harm, when care is taken. They are conducted much in the same way as in cold countries, except that the very early morning is usually chosen. The men are roused at half-past two or three, and parade half an hour later; the tents are struck, and carried on by the tent-bearers; coffee is served out, and the men march off by half-past three or four, and end at half-past seven. Everything is ready at the halting-ground, tents are pitched, and breakfast is prepared.

These very early marches are strongly advocated by many, and are opposed almost as strongly by some. In the West Indies, marching in the sun has always been more common than in the East. Much must depend on the locality, and the prevalence and time of hot land winds. Both in India and Algeria marches have been made at night; the evidence of the effects of this is discordant. The French have generally found it did not answer; men bear fatigue less well at night; and it is stated that the admissions into hospital have always increased among the French after night marching. Annesley's authority is also against night marching in India. On the other hand, I have been informed that in India the march through the cool moon-light night has been found both pleasant and healthy.

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* The following is a very good lotion for sprains: sal ammoniac, 20 grains, vinegar and spirit, an ounce of each.

Afternoon marches (commencing about two hours before sunset) have been tried in India, and, I believe, often with very good results.

*Marching in Canada.*—In 1814, during the war with America; in 1837, during the rebellion; and, in 1861–62, during the "Trent" excitement, winter marches were made by the troops, in all cases without loss. The following winter clothing was issued at home:—A sealskin cap with ear lappets; a woollen comforter; two woollen jerseys; two pairs woollen drawers; a chamois leathern vest with arms; two pairs long woollen stockings to draw over the boots; sealskin mits, and a pair of jackboots. In Canada a pair of blankets and moccasins were added,* and, at the long halts, weak hot rum and water was served out. A quarter of a pound of meat was added to the ration. A hot meal was given before starting, another at mid-day, and another at night. The troops were extremely healthy. During exposure to cold, spirits must be avoided; hot coffee, tea, ginger tea, or hot weak wine and water, are the best; it is a good plan to rub the hands, feet, face, and neck with oil; it appears to lessen the radiation of heat and the cooling effect of winds.

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* See Inspector-General Muir's Report—Army Medical Report, vol. iv. p. 378.

## CHAPTER III.

# THE EFFECTS OF MILITARY SERVICE.

THE influence of the various conditions of military life is shown by the records of sickness and mortality, and this must be noted in the various stations.

The recruit having entered the ranks, begins his service at home, and he is kept at his depôt for some time. He does not go to India until he has completed his twentieth year, although he may take other foreign service earlier. We should suppose his life would be a healthy one. It is a muscular, and, to a certain extent, an open-air life, yet without great exposure or excessive labour; the food is good (though there might be some improvement), the lodging is now becoming excellent, and the principles of sanitation of dwellings are carefully practised. Although the mode of clothing might be improved as regards pressure, still the material is very good. There is a freedom from the pecuniary anxiety which often presses so hardly on the civil artisan, and in illness the soldier receives more immediate and greater care than is usual in the class from which he comes.

There are some counterbalancing considerations. In a barrack, there is great compression of the population, and beyond a doubt the soldier has greatly suffered, and even now suffers, from the foul air of barrack rooms. But this is a danger greatly lessening, owing to the exertions of the Barrack Improvement Commissioners, and, as is proved by the experience of some convict jails, can be altogether avoided.

Among the duties of the soldier is some amount of night-work; it is certain that this is a serious strain, and the Sanitary Commissioners, therefore, inserted in the Medical Regulations an order that the number of nights in bed should be carefully reported by medical officers. Commanding officers should be informed how seriously the guard and sentry duties, conducted as they are in full dress, tell on the men if they are too frequent; one guard-day in five is quite often enough, and four nights in bed should be secured to the men. Exposure during guard and transition of temperature on passing from the hot air of the guard-room to the outside air are also causes of disease. The weights and accoutrements are heavy, but the valise equipment introduced by General Eyre's Committee has removed the evil of the old knapsack.

The habits of the soldier are unfavourable to health; in the infantry, especially, he has much spare time on his hands, and *ennui* presses on him. *Ennui* is, in fact, the great bane of armies; though it is less in our own than in many others. It is said to weigh heavily on the German, the Russian, and even on the French army. Hence, indeed, part of the restlessness, and one of the dangers of large standing armies. The Romans appear to have avoided this danger by making their distant legions stationary, and permitting marriage and settlement—in fact, by converting them into military colonies. We avoid it in part by our frequent changes of place, and our colonial and Indian service; but not the less, both at home and abroad, do idleness and *ennui*, the parents of all evils, lead the soldier into habits which sap his health.

Not merely excessive smoking, drinking, and debauchery, but in the tropics mere laziness and inertia, have to be combated. Much is now being done by establishing reading-rooms, trades, industrial exhibitions, &c., and by the encouragement of athletic sports to occupy spare time, and already good results have been produced.

The establishment of trades, especially, which will not only interest the soldier, but benefit him pecuniarily, is a matter of great importance. It has long been asked why an army should not do all its own work; give the men the hope and opportunity of benefiting themselves, and *ennui* would no longer exist. In India, Lord Strathnairn did most essential service by the establishment of trades; and the system, after long discussion and many reports, is now being tried in England.

One of the proofs of ability for command and administration is the power of occupying men, not in routine, but in interesting and pleasant work, to such an extent that rest and idleness may be welcomed as a change, not felt as a burden. Constant mental and much bodily movement is a necessity for all men; it is for the officers to give to their men an impulse in the proper direction.

Among the conditions of the soldier's life adverse to health, enforced celibacy must be reckoned. This produces not merely promiscuous intercourse, that terrible evil, but other effects. We do not require the statistical proof that both in the army and civil life married men have less illness and longer lives than single men; we might be certain, *a priori*, that the great function of procreation cannot be thus endangered by the conditions we impose on our soldiers without injury. The continental system of conscription for limited periods has prevented this matter from assuming the importance it does in armies enlisted for long or permanent service. For our own army the question is pressing enough, nor is it easy to offer a solution, unless the system of short service is found to have a good effect.

The last point which, probably, makes the soldier's life less healthy than it would otherwise be, is the depressing moral effect of severe and harassing discipline. In our own army in former years, it is impossible to doubt that discipline was not merely unnecessarily severe, but was absolutely savage. An enlightened public opinion has gradually altered this, and with good commanding officers, the discipline of some regiments is probably nearly perfect; that is to say, regular, systematic, and unfailing; but from its very justice and regularity, and from its judiciousness, not felt as irksome and oppressive by the men.

The general result of the life at home on soldiers must now be considered.

It is by no means easy to say whether soldiers enjoy as vigorous health as the classes from which they are drawn; the comparison of the number of sick, or of days' work lost by illness by artisans, cannot be made, as soldiers often go into hospital for slight ailments which will not cause an artisan to give up work. The comparative amount of mortality seems the only available test, though it cannot be considered a very good one.

Following the order laid down in the chapter on STATISTICS, we have to consider—

## SECTION I.

## THE LOSS OF STRENGTH BY DEATH AND INVALIDING, PER 1000 PER ANNUM.

### *A.* BY DEATH.

It is to be understood that the mortality is here reckoned on the strength, that is, on the total number of healthy and sick persons actually serving during the time. The mortality on the sick alone is another matter.

From the Parliamentary Statistical Returns of the Army (1840 and 1853, which include the years 1826–1846), we find that the mortality among the cavalry of the line was at that time about ⅓d more than among the civil male population at the same age (nearly as 15 to 10[*] per 1000); among the Foot Guards it was more than double (very nearly 20½ per 1000 as against 10); among the infantry of the line it was ¾ths more (or 18 per 1000 as against 10).

The State was thus losing a large body of men annually in excess of what would have been the case had there been no army, and was therefore not only suffering a loss, but incurring a heavy responsibility.

In the splendid men of the Household Brigade, diseases of the lungs (including phthisis) accounted for no less than 67·7 per cent. of the deaths, in the cavalry of the line for nearly 50 per cent., and in the infantry of the line for 57 per cent.; while among the civil population of the soldier's age, the proportion in all England and Wales was only 44·5 per cent. of the total deaths. The next chief causes of deaths were fevers, which accounted in the different arms of the service for from 7 to 14 per cent. of the total deaths. The remainder of the causes of deaths were made up of smaller items.

These remarkable results were not peculiar to the English Army. Most armies did, some still do, lose more than the male civil population at the same age. The following are the most reliable statisics:—[†]

| | Army Loss Per 1000. | | Army Loss Per 1000. |
|---|---|---|---|
| France (1823), | 28·3 | Prussian [§] (1867), | 6·54 |
| France (Paixhans, 1846), | 19·9 | Russian [‖] (series of years), | 39 |
| France, mean of 7 years (1862–68), | 10·0 | „ (1857–1866), | 18·7 |
| France (1869), | 9·55 | Austrian, | 28 |
| France (1872), | 9·49 | „ (1869), | 11·58 |
| French in Algeria (1846), | 64 | Piedmontese (1859), | 16 |
| „ „ (1862–66), | 14·98 | Italian (1870), | 8·40 |
| Prussian [‡] (1846–1863, excluding officers), | 9·49 | United States (before the war), | 18·8 |
| Prussian (1869), | 6·10 | Portuguese (1851–53), | 16·5 |
| Prussian army (including the Saxon and Würtemberg corps (1876), | 4·96 | Danish, | 9·5 |

The old Hanoverian army was very healthy, losing only 5·3 per 1000 as against 9·5 among the civil population of the same ages.

In these foreign armies the same rule holds good; fevers (chiefly typhoid in all probability) and phthisis were the great causes of mortality. In Prussia phthisis formerly caused 27 per cent. of the total mortality, but in that army phthisical men are sent home, and after a certain time are struck off the rolls, so that the army deaths are thus fewer than they would be if the men died at their regiments. In Austria phthisis caused 25 deaths out of every 100; in France, 22·9;[¶] while in 1859, the proportion among the civil population was 17·76; in Hanover, 39·4; and in Belgium, 30; though in the latter country the proportion among the civil population was only 18·97 deaths from phthisis per 100 of all deaths. In Portugal the mortality from phthisis constitutes 22 per cent. of the deaths,* while in the civil population the deaths are 12 per cent. of the total deaths. In the Prussian army in 1876 only 16 per cent. were from phthisis. In these armies, also, fevers caused a greater number of the deaths than in the English army, even in the period referred to. In Prussia, 36 (reduced in 1876 to 20); in France, 26;† in Belgium, 16·6; and in Hanover, 23·68 per cent. of all deaths were from fever (typhoid?). In Portugal only 3·9 deaths are from typhoid out of every 100 deaths; this is owing to its rarity in the country districts; it is common in Lisbon.

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[*] In reality the deaths from the civil male population of the soldiers' ages (20 to 40) were below 10, and in the healthy districts much below; the case against the soldier is, therefore, even worse than it reads in the text.

[†] Meyne (Eléments de Stat. Méd. Militaire, 1859) gives some of these figures; others are taken from the reports of the different armies.

[‡] Dr Engel, in Zt. des Königl. Preussich. Stat. Bureaus, Aug. Sept. 1865, p. 214.

[§] Stat. Sanitäts-bericht über die Kon. Pr. Armee, for 1867, Berlin, 1870. Without deaths of invalids the mortality was only 6·196. The men were all under thirty years of age, which must be taken into account.

[‖] The Russian mortality has lately been greatly reduced.

[¶] This was in 1860; I have calculated this from Laveran's returns from eleven of the great garrisons.

Nothing can prove more clearly that in all these armies the same causes were in action. And from what has been said in previous chapters, it may be concluded that the reason of the predominance of these two classes, lung diseases and typhoid fever, must be sought in the impure barrack air, and in the defective removal of excreta.

The Crimean war commenced in 1854, and ended in 1856. A large part of the army was destroyed, and a fresh force of younger men took its place. Soon afterwards, the great sanitary reforms of Lord Herbert commenced. In 1859 yearly statistical returns began to be published.

The mortality of all arms has undergone an extraordinary decrease from that of the former period.

*Mortality per* 1000 *per Annum.*

| | From all Causes. | From Disease alone (*i.e.*, excluding violent deaths). |
|---|---|---|
| Mean of ten years, 1861–70, . | 9·45 | 8·534 |
| 1871, . . . . | 8·62 | 7·800 |
| 1875, . . . . | 9·36 | 8·440 |
| 1876, . . . . | 8·43 | |

The diminution over the years previously noted (1826–46) is extraordinary. Three causes only can be assigned for it—the youth of the army, and a better selection of men; or a partial removal of the causes of diseases; or earlier invaliding, and the action of the Limited Enlistment Act, so as to throw the fatal cases on the civil population.

The question of age has been examined and disposed of by Dr Balfour,‡ who has shown that the youth of the army does not account for the lessening. Selection has always been made with equal care, and invaliding, though it certainly has been greater of late years, does not appear to have been in excess sufficient to account for the lessening. There can be no doubt, then, that the great result of halving the yearly loss of the army by disease has been the work of Lord Herbert and the Royal Sanitary Commission.

It will be observed that the diminution in the mortality in the French army has also singularly lessened from 1846 to 1862 and 1863, and this is, no doubt, owing to the great sanitary precautions now taken in that army.

It is curious to observe that in the French and English armies the mortality is now almost the same, viz., about 9·5 per 1000 present with the colours; it is slightly the lower in the English. The Prussian was about the same, but is now much less, owing probably to the greater youth of the army.

Of the different arms of the service, the cavalry and artillery are rather healthier than the infantry; the engineers than either; the officers always show less mortality than the non-commissioned officers and privates, and the non-commissioned officers less than the privates. In different regiments there is often a singular difference in the mortality in a given year, but this is usually easily accounted for, and in a term of years the differences disappear.

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* Marques, reviewed in an excellent article in the British and Foreign Medico-Chir. Review for April 1863.

† Laveran, in 1860, made the number 25·9 in the deaths from eleven garrisons. In 1863, the mortality from typhoid in the French army was 1·87 deaths per 1000 of effectives in France, 1·63 in Algeria, and 3·55 in Italy. In 1866 the mortality was 1·45 in France, 1·39 in Algeria, and 2·25 in Italy.

‡ Report for 1859, p. 6.

### *Comparison with Civil Population.*

This gross mortality must now be compared with that of the civil population. In England the gross male civil mortality at the soldier's age is—*

| | Mortality per 1000 of Population. |
|---|---|
| From 20 to 25 years of age, . . . . . . . . | 8·83 |
| 25 to 35 „ . . . . . . . | 9·57 |
| 35 to 45 „ . . . . . . . | 12·48 |

The soldier's mortality, taken as a whole, is therefore not above that of the civil population, but then there is invaliding, and some uncertain addition should be made to the mortality on this account.

Comparing the soldier's mortality (invaliding being disregarded) with trades, he is rather more unhealthy than carpenters (7·77), labourers (7·92), bakers (7·94), blacksmiths (8·36), grocers (8·4), farmers (8·56), weavers and cotton-spinners (9·1), and shoemakers (9·33).† But he is healthier than butchers (9·62), miners (9·96), tailors (11·62), and publicans (13·02).

### *Influence of Age on the Mortality.*

The following table from Dr Balfour gives the results, excluding the depôts :—

| | Per 1000 of Strength. | | | | | |
|---|---|---|---|---|---|---|
| | Under 20. | 20 and under 25. | 25 and under 30. | 30 and under 35. | 35 and under 40. | 40 and upwards. |
| 1865–74 (10 years), | 3·03 | 5·27 | 6·35 | 12·24 | 17·55 | 23·82 |
| 1875, . . . . | 3·58 | 4·40 | 8·68 | 10·82 | 17·24 | 22·20 |
| Civil male population in England and Wales, | 7·41 | 8·2 | 9·21 | 10·23 | 11·63 | 13·55 |
| Healthy districts, | 5·83 | 7·3 | 7·93 | 8·36 | 9·00 | 9·86 |

The number of soldiers under 20 years of age is so small that no conclusions can be drawn; but it would appear that from 20 to 30 the mortality is favourable to the soldier, but after that the proportion is reversed, and the soldier dies more rapidly than the civilian. And if to this we call to mind the invaliding from the army, it seems clear that a prolonged military career is decidedly injurious, either from causes proper to the career, or to personal habits engendered in it.

### *Causes of Mortality.*

In order to see the principal causes of the eight or nine deaths which occur annually among 1000 men, I have calculated the following table from Dr Balfour's most useful Reports :—

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* In France, in 1866, the mortality was—

| | Per 1000 of Population. | |
|---|---|---|
| Years. | With Military Deaths. | Military Deaths excluded. |
| 20 to 25, . . . . . | 10.12 | 10·1 |
| 25 to 30, . . . . . | 9·5 | 9·47 |
| 30 to 35, . . . . . | 9·7 | 9·66 |

Vallin in Ann. d'Hyg. Jan. 1869, p. [illegible]. The year was, however, a choleraic year.

† Dr Farr's numbers, in the Supp[illegible] to the 25th Report of the Registrar-General, p. xvi.

### *Causes of Mortality.**

| | Mortality per annum per 1000 of Strength (1867–71, 5 years). | Deaths in 100 Deaths (1867–71, 5 years). | Deaths in 100 Deaths (1859–66, 8 years). | Deaths in 100 Deaths (1872–75, 4 years). |
|---|---|---|---|---|
| Phthisis and tubercular hæmoptysis, . | 2·648 | 30·26 | 33·81 | 28·0 |
| Diseases of heart and vessels, . . | 1·462 | 16·71 | 9·01 | 16·7 |
| Pneumonia, . . | ·777 | 8·88 | 6·54 | † |
| Violent deaths, . | ·598 | 6·84 | 6·32 | 6·3 |
| Diseases of nervous system, . . | ·576 | 6·58 | 6·60 | 6·7 |
| Continued fevers, chiefly enteric, . | ·405 | 4·63 | 5·68 | 4·4 |
| Suicides, . . | ·288 | 3·30 | 3·03 | 2·5 |
| Bronchitis, . . | ·167 | 1·91 | 5·47 | † |
| Delirium tremens, . | ·069 | ·80 | ·90 | † |
| All other causes, . | 1·756 | 20·07 | 22·55 | 21·3 |

This table must now be analysed more particularly.

### 1. *Tubercular Diseases.*

The deaths from phthisis and hæmoptysis in the eight years ending 1866 averaged 3·1 annually per 1000 of strength, the highest annual ratio being 3·86, and the lowest 1·95. In 1867–71 the mean mortality was 2·648 per 1000, in 1872–75, 2·34. In addition to this there was invaliding for phthisis, and thus a certain number of deaths were transferred from the army to the civil population. The following table shows the exact number in four branches of the service (two cavalry and two infantry) in seven years.

TABLE *to show the Deaths and Invaliding per annum from Phthisis and Hæmoptysis in Household Cavalry, Cavalry of the Line, the Foot Guards and Infantry of the Line (mean of seven years,* (1864–70).

| Phthisis and hæmoptysis, taken from Abstract in Appendix to Dr Balfour's Report. | Household Cavalry. | Cavalry of Line. | Foot Guards. | Infantry of Line. |
|---|---|---|---|---|
| Died per 1000, . | 3·763 | 1·416 | 2·300 | 2·120 |
| Invalided per 1000, | 8·234 | 4·025 | 9·491 | 5·510 |
| Total died and invalided per 1000, | 11·997 | 5·441 | 11·791 | 7·630 |

This table shows a considerable difference between the branches of the service; the mortality and invaliding of the household troops are much the highest. The mortality from tuberculosis of the infantry of the line is below the mean mortality of the army at large; the mortality of the cavalry of the line below that of the infantry.

It is quite clear (and the same thing is seen in the earliest records) that there is an excessive rate of mortality and invaliding from phthisis in the regiments serving in London, which points to some influences acting very injuriously upon them. During the later years, however, the mortality and invaliding in the foot guards has decreased. In the four years ending with 1870, the mortality was only 2·08, and the invaliding 8·213 per 1000; that the improvement has continued may be seen by the following table:—

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* This table has been calculated from the numbers in Appendix I. of Dr Balfour's Report in the Army Med. Department Blue Books (1859–71), and from the subsequent volumes 1872–75.)

† The abridged form in which the statistics have been published since 1874 prevents these numbers being given in detail. The number of deaths from respiratory diseases would be about 14 in 100.

*Table similar to one on page* 609, *for 5 years*, 1871–75.

| Phthisis, &c. | Household Cavalry. | Cavalry of Line. | Foot Guards. | Infantry of Line. | Depots, 1873–75. |
|---|---|---|---|---|---|
| Died per 1000, . | 3·644 | 1·736 | 2·086 | 2·096 | 3·990 |
| Invalided per 1000, | 3·662 | 4·348 | 6·818 | 4·732 | 8·237 |
| Total died and invalided per 1000, | 7·306 | 6·084 | 8·904 | 6·828 | 12·227 |

From this table it may be seen that an improvement is decidedly taking place, except in the cavalry of the line and the depôts, there being a slight increase in the former and a very high and increasing rate in the latter.

How does this mortality compare with that of the male civil population at the soldiers' ages?

*Mortality from Phthisis.*

| Male Civilians.* | Age. | |
|---|---|---|
| All England and Wales, . . | 20 to 25 | 3·5 |
| " " . . | 25 " 30 | 4·0 |
| " " . . | 30 " 35 | 4·1 |
| " " . . | 35 " 40 | 4·1 |
| " " . . | 15 " 55 | 3·7 |
| " " . . | 25 " 45 | 4·02 |
| London, . . . . . . | 15 " 55 | 4·5 |
| Worst districts in England, excluding hospitals, | | 5·0 |
| Best districts in England, . . . . | | 1·96 |

The deaths in the army from phthisis and hæmoptysis do not exceed the deaths in the population generally. They are, however, much greater than in the best districts in England, though fewer than in the worst. But in the army there is invaliding also; that is, men with a fatal disease are discharged into the civil population. Taking this into consideration, as expressed in the table just given, it seems certain that phthisical disease is in excess in the army as compared with the male civil population.

Did the army suffer more from phthisis in former years than it does now? The following table will answer this question:—

*Deaths from Phthisis per* 1000 *of Strength.*

| | Years 1830–36 =7 years. | Years 1837–46 =10 years. |
|---|---|---|
| Household Cavalry, . . . . . | 7·4 | 6·28 |
| Cavalry of the Line, . . . . . | 5·29 | 5·65 |
| Foot Guards, . . . . . . | 10·8 | 11·9 |
| Infantry, . . . . . . . | ... | 7·75 |
| Mean, . . . . | 7·83 | 7·89 |

During these two periods, which make a total of seventeen years, the mortality was 7·86 per 1000, and there was no decline in the later as compared with the earlier period.

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* Parliamentary Return of Annual Average Mortality during the Decennial Period, 1851–60, Feb. 1864; and Dr Farr's Report to the Sanitary Commission, p. 507.

But as in the eight years ending with 1866 the mortality was only 3·1 per 1000, there must have been an enormous excess of mortality in the earlier period, unless it can be explained in some way.*

(*a*) In the earlier periods the mortality from chronic bronchitis was included in the phthisical mortality. If a correction is made for this, the mortality of the period 1859–1866 rises only to 3·3; so that will not explain the difference.

(*b*) Was the invaliding more active in the last period, so as to lessen the deaths occurring in the army below what would have taken place without invaliding? I have not been able to learn the amount of invaliding in the earlier period, but I have been told there is no reason to think it was less than subsequently, but, on the contrary, it was very large from the foot guards. That invaliding cannot account for the difference is seen by the fact that the annual deaths per 1000 in the seventeen years ending 1846 (viz., 7·86) were more numerous (in the cavalry and infantry of the line) than deaths and invaliding together in the period of five years ending 1871.

(*c*) The Limited Enlistment Act, by which a certain number of weakly men may possibly have left the army, has been in action in the last period. I cannot estimate the amount of this action, but it is in the highest degree improbable that it has much direct effect; for if a man of nearly ten years' service were ill with phthisis, he would be sure to get invalided, in order to enjoy his temporary pension for two or three years, and would not simply take his discharge.

(*d*) The lessened age of the army at large, if the Limited Enlistment Act has produced that effect, might perhaps have had some effect, as mortality from phthisis increases with age in the French army, and probably in our own; but this would never account for the astonishing difference; for in the French army the increase from phthisis of the men over fourteen years' service, as compared with those under, is only one per 1000 of strength.

I conclude, then, that there was a greater excess of the disorganising lung diseases classed as phthisis in the earlier period (1830–46). The amount of phthisis strongly attracted the attention of Sir Alexander Tulloch and Dr Balfour in 1839. They state that in the Equitable Assurance Company at that time the annual mortality (at the ages 20 to 40) from disease of the lungs was 3·4 per 1000; while in the years 1830–36 the mortality from disease of the lungs among the foot guards was no less than 14·1 per 1000, of which phthisis alone caused 10·8.†

How does our army contrast with others?

In France the deaths from phthisis and chronic bronchitis together amount to 2·75 per 1000 of "present," but some die "*en congé*;" and it is probable that there is at present as much phthisis in the French as in our own army. In the Prussian army the men are also discharged early, so that comparison is difficult.

In the Prussian army the mean yearly mortality from laryngeal and lung phthisis was 1·28 per 1000 of strength (years 1846–63); in 1000 deaths there were 13·57. I do not know the amount of invaliding.

We may conclude, then, with regard to phthisis—

1. That it was formerly in enormous excess in the army over the civil population, and particularly in the foot guards; in other words, a large amount of consumption was generated.

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* In the 9 years ending with 1875 it was only 2·51 per 1000.

† In commenting on this fact the reporters say (Army Medical Report of 1839, p. 13)—"If the aggregation of a number of men into one apartment, even though the space is not very confined, creates a tendency to this disease, then it clearly points out the propriety of affording the soldier as ample barrack accommodation as possible." Thus, even at that time, it was seen that no other cause but overcrowding could account for the great amount of lung disease.

2. That there has been a great decline of late years, though there is still in all probability some excess, especially in the household troops.

What are the causes of this phthisical excess in the years 1830–46. It is noticeable that in the earlier periods all affections of the lungs were also in excess, and we can readily see that a number of antecedents may combine in producing the result, and that destructive lung diseases may proceed from many causes. Still there must have been some predominating influence at work.

The phthisis was not owing to climate, for that is unchanged. Moreover, we shall hereafter see that the same excess was seen in the Mediterranean stations and the West Indies.

It was not owing to syphilis, for until late years, the amount of syphilis has rather increased than diminished, while phthisis has lessened.

It was not owing to bad food, for the food was the same in all the branches, and yet the amount of phthisis was widely different. Besides, the food has been comparatively little altered.

It can hardly have been the duties or clothing, for there has been no sufficient change in either to account for the alteration, unless the abolition of one of the cross-belts some years ago had some effect. But then this would have only affected the infantry.

It must have been some conditions acting more on the foot guards than in the household cavalry, and less in the line regiments; also it must have been acting in the troops stationed in the Mediterranean and the West Indies. There is only one condition common to all which seems capable of explaining it, and that the cause noticed in the Report of 1839, viz., overcrowding. This condition was, and is still most marked in the barracks of the foot guards, and least in the barracks of the cavalry of the line. It is the only condition which has undergone a very decided change both at home and abroad. This consideration, as well as those formerly noticed in the section on Air, seems to me to make it almost certain that the breathing the foul barrack atmosphere was the principal, perhaps the only, cause of this great mortality from lung diseases. If this be so, it shows that the foot guards are still the worst housed of any troops.

### 2. *Diseases of the Heart and Vessels.*

The fact that diseases of the circulatory system rank second as causes of death in the army at home may well surprise us. It is marked in all arms, as much in the artillery and cavalry as in the infantry. The ratio per 1000 of strength for the five years (1867–71) for all diseases of the organs of circulation was 1·462, and in those years out of every 100 deaths no less than 16·7 were from disease of the heart and vessels. In addition, there was a large amount of invaliding from this cause.

If the fatal diseases of the circulatory system of the five years (1867–71)* are divided into two classes, those referred to some disease of the heart itself (chiefly chronic), and those referred to aneurism (including an occasional rare return headed "Degeneratio Aortæ"), it is found that the deaths are :—

| | Per 1000 of Strength. | In 100 Deaths. |
|---|---|---|
| From cardiac disease, . . . | ·727 | 8·31 |
| From aneurism, . . . . | ·735 | 8·4 |
| Total, . . . . | 1·462 | 16·71 |

These numbers are higher than those of the nine years (1859–67), when the mortality from circulatory diseases was only ·908 per 1000 of strength, and the percentage on the total deaths was 9.

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* In the recent returns the differential diagnosis is not given. In 1875 the deaths per 1000, from diseases of the circulatory system, were 1·37, and the percentage of total deaths, 17·24.

This mortality is in excess of that of the civil male population of the same age, especially as regards aneurism. Dr Lawson has calculated that aneurism is eleven times more frequent among soldiers than civilians; and he has also calculated that among civilians, aged 15 to 44, the ratio of mortality from cardiac affections alone is ·45 per 1000. The army, then, in the years 1867–71, had an excess of ·277 per 1000 of heart disease. Myers' statistics are confirmatory The amount of heart disease is greater among the foot guards than among the metropolitan policemen. Myers in his able treatise* gives the following numbers :—

| | Died per 1000 | Invalided per 1000. |
|---|---|---|
| Foot Guards, . . . . | ·8 | 3·2 |
| Police, . . . . . | ·29 | 1·37 |

It is greater among soldiers than sailors; from six years' observations (1860–65) Myers† makes the navy mortality ·66, and the invaliding 3·44 per 1000; while in the army in the same years the mortality was ·9, and the invaliding 5·26.

If the different arms of the service are taken, the following numbers are given by the five years 1867–71 :—

| | Cavalry of Guard. | Cavalry of Line. | Artillery. | Foot Guards. | Infantry of Line. |
|---|---|---|---|---|---|
| Mean yearly strength, . . | 1,213 | 8,468 | 9,417 | 5,749 | 31,729 |
| Total deaths from disease of the heart in five years, . . . | 1 | 24 | 57 | 19 | 73 |
| Total deaths from aneurism in five years, . . . . | 2 | 37 | 49 | 20 | 103 |
| Heart deaths per 1000 of strength, | ·181 | ·566 | 1·210 | ·661 | ·460 |
| Aneurismal deaths per 1000 of strength, per annum, . . | ·329 | ·873 | 1·041 | ·695 | ·649 |

The numbers in the household cavalry are so small, it is not safe to use them; but the other numbers are sufficiently large to render it probable that the artillery show a larger proportion of fatal cardiac and aneurismal cases than any other body of troops. The line cavalry and line infantry both show rather an excess of aneurismal over heart deaths; while the artillery show more heart than aneurismal deaths, and in the foot guards the proportion is equal. The point which comes out clearly from the table, in addition to the large amount in all, is the excess of both classes of deaths in the artillery; that it is a real excess is seen by comparing the yearly number of the artillery and cavalry of the line who did not differ greatly in mean strength. The production of these diseases of the circulatory organs begins very early in the military career. In 1860–62 I calculated out the causes of invaliding in 6856 men. Of these 1014 were under two years' service. In the whole number the percentage of heart and vessel disease as the cause of the invaliding was 7·7; among the men under two years' service it was 14·23 per cent. As these men had presumably healthy hearts when they enlisted, the effect both of the military life in producing diseases of the circulatory organs, and the greater suffering from it of young soldiers, seems certain. The statistics in the Knapsack Committee's Report confirm this.

The cause of this preponderance in the army of diseases of the circulatory organs is a matter of great importance. Whatever they may be, it is probable that they produce both the cardiac and the arterial disease.

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* Diseases of Heart among Soldiers, by A. B. R. Myers, Coldstream Guards. London 1870.

† Diseases of Heart among Soldiers, p. 11.

The two most common causes of heart disease in the civil population are rheumatic fever in young, and renal disease in older persons. The latter cause is certainly not acting in the army, and the former appears quite insufficient to account for the facts. A great number of the men who suffer from heart and vessel disease have never had acute rheumatism; and if we refer the affection to slight attacks of muscular rheumatism, which almost every man has, we are certainly going beyond what medical knowledge at present warrants. The effect of lung disease in producing cardiac affections is also not seen in the army to any extent.

The influence of syphilis in producing structural changes in the aortic coats was noticed by Morgagni. In 114 post mortem examinations of soldiers dying at Netley, Dr Davidson[*] found 22 cases of atheroma of the aorta. Of those 17 had a syphilitic history, 1 was doubtful, and 4 had had no syphilis, but had heart and lung diseases. Of the whole 114 cases, 78 had no syphilitic history and had 4 cases of atheroma, or 5·1 per cent.; 28 had a marked syphilitic history and 17 had atheroma, or no less than 60·7 per cent. This seems very strong evidence as to atheroma. With respect, however, to actual aneurism, no corresponding analysis of cases has been made, and therefore at present the effect of syphilis must be considered uncertain; but it is quite clear, even admitting its influence, there is no reason to think that syphilis prevails more among soldiers than among the civil male population of the same class. It is, therefore, unlikely that an excess of syphilis, if it really occurs among soldiers, and if it actually predisposes to aneurism, as seems probable, could produce 11 times as many aneurisms as in civil persons. Myers has also given evidence that both in the army and navy aneurism is sometimes not preceded by degeneration of the arterial coats, and in these cases mere improper exertion seemed to produce it.

The effect of excessive smoking again has been assigned as a cause of the soldier's cardiac disease; but no one who knows the habits of many continental nations, and of some classes among our own, could for a moment believe this to be the cause.

Again, the effects of alcohol in constantly maintaining an excessive action of the heart, are so marked as to make it highly probable that this is a fact of great importance; but soldiers do not drink so much, as compared with civilians, as to lead us to think the cause can explain the prevalence.

There is, however, one cause which is continually acting in the case of soldiers, and that is the exertion (often rapid and long continued) which some of the duties involve.[†] The artillery have very heavy work; often it is very violent and sudden, more so perhaps than in any other corps; the cavalry also have sudden work at times; and the infantry soldier, though his usual labour is not excessive, is yet sometimes called upon for considerable exertion, and that not slowly, or with rests, but with great rapidity. And this exertion is in all arms undertaken with a bad arrangement of dress and of equipments. The cavalry and artillerymen are very tightly clothed, and though the horse carries some of the burden, it is, I believe, undoubted that the men are overweighted. In the infantry, till lately, they wore very tight-fitting tunics, with collars made close round the neck, and trousers (which were often kept up by a tight belt); there was a broad strap weighted below with a heavy pouch and ammunition, crossing and binding down the chest; and there was the knapsack constricting the upper part of the chest, and hindering the air from passing into the proper lobes.

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[*] Army Medical Department Report, vol. v. p. 481.

[†] For a full and able discussion on all those points, and for additional evidence, I must refer to Mr Myers' excellent work. On the effect of exertion during war in causing cardiac hypertrophy, I may refer to Dr Fräntzel's paper in Virchow's Archiv, band lvii. p. 215.

The production of heart disease ought not to be attributed solely to the knapsack, as is sometimes done; the knapsack is only one agency; the cross-belt was probably worse, and the tight clothes add their influence. But even with the knapsack alone the effect on the pulse is considerable, and one or two of my experiments may be given in illustration. Thus, four strong soldiers carried the old regulation knapsack, service kit, greatcoat, and canteen, but no pouch and no waist-belt (except in one man). The pulse (standing) before marching was on an average 88; after 35 minutes it had risen on an average to 105; after doubling 500 yards, to 139, and in one of the men was 164, irregular and unequal. After the double they were all unfit for further exertion. In a fifth man, who was not strong, the 35 minutes' marching raised the pulse from 120 to 194; after doubling 250 yards he stopped; the pulse then could absolutely not be felt. In another series, the average pulse of four men, with the knapsack only, was 98 (standing), after one hour's march, 112; after their doubling 500 yards, 141. If the pouch with ammunition is added the effect is still greater. I have taken the pulse and respirations after long marches, and found the effect still more marked. Walking, of course, will quicken the pulse and respiration in any man, but not to such an extent, and the sense of fatigue in unincumbered men is much less.

In the lecture, formerly alluded to,* my colleague, Dr Maclean, put this matter most forcibly before the authorities, and I believe he is quite justified in the expression that one great cause of the cardiac (and perhaps of the aortic and pulmonary) disease in the army is to be found in exertion carried on under unfavourable conditions.

Happily, much has been lately done by the authorities to remove this cause; but still, especially in the artillery and mounted service,† changes appear to be necessary, and in all arms it is desirable that officers should allow their men to do their work under the easiest conditions, as regards clothes, weights, and attitudes, consistent with military discipline and order.

### 3. *The Nervous Diseases.*

These form a very heterogeneous class: apoplexy, meningitis, paralysis, mania, &c., are the chief headings. The proportion to 1000 of strength is about ·6, and 6·6 deaths of every 100 are owing to nervous diseases. As among the male civil population (ages 25 to 35) the deaths are also 6·6 per cent. of total deaths, soldiers do not appear to suffer more.

### 4. *Pneumonia and Acute Bronchitis.*‡

TABLE to show the admissions and deaths per annum per 1000 of strength, years 1859–71 (13 years).

| | Pneumonia. | | Acute Bronchitis. | |
|---|---|---|---|---|
| | Admissions. | Deaths. | Admissions. | Deaths. |
| Average, . . . . . | 5·25 | ·641 | 55·65 | ·227 |
| Highest in thirteen years, . | 7·18 | ·741 | 88·00 | ·38 |
| Lowest in thirteen years, . | 3·49 | ·423 | 39·10 | ·08 |

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* Royal United Service Institution Journal, 1863, vol. viii.

† The cardiac diseases are of the most varied kind. I have seen at Netley, in Dr Maclean's wards, in one hour in the summer, when the hospital is full, almost all the combinations of heart affections. It has appeared to me that if anything gives the tendency to heart affections, then the dress and the accoutrements come in as accessory causes, and prevent all chance of cure. In some cases there is no valvular disease, and not much hypertrophy of the heart, but singular excitability, so that the heart beats frightfully quick on the least exertion.

‡ Separate data are not published for the later years.

The acute inflammatory diseases of the lungs give, therefore, a mean annual mortality of ·856 per 1000 of strength·

In the French army pneumonia gives a lower, and acute bronchitis a higher, mortality than in our own, but this is perhaps a mere difference of nomenclature.

The opinion that the military suffer more than the civil population from pneumonia is an old one. It is also generally believed that they suffer less in the field than in garrison. I have been unable to find statistics that satisfy me as to the amount among the civil population. In the European population, generally, Ziemssen * gives the deaths from pneumonia as 1·5 ; and Oesterlen,† 1·25 per 1000 ; but this includes all ages, and both sexes. Among men alone it is certainly greater than among women. In London, in 1865, the mortality from pneumonia, between the ages 20 and 40 (both sexes), was 1 per 1000 population. ‡

If this be correct, the mortality among soldiers is below the civil mortality, or soldiers are less subject than civilians ; for, as men are more subject to pneumonia than women, the mortality among the civilian males would be greater than 1 per 1000, but the military mortality is only ·641. The mortality among the army pneumonic cases (deaths to treated), amounts (average of thirteen years) to 12·18 per cent.,§ and as this is very nearly the civil proportion, every 1000 of population in London gave nine cases of pneumonia, while 1000 soldiers gave only five. It may be said, however, that London is not a fair test ; but as a place of residence for soldiers it does not appear to predispose to pneumonia, as will be seen from the following table :—

| | Per 1000 of Strength. years 1864–71. | |
|---|---|---|
| | Foot Guards in London. | Infantry in the Kingdom generally. |
| Admissions from pneumonia, . . . . | 3·75 | 6·06 |
| Deaths from pneumonia. . . . . | ·44 | ·66 |

The mortality to cases treated in the five years 1867–71 was, in the Guards, 10·68, and in the infantry, 11·7 per cent.

Although I do not see that pneumonia (and acute bronchitis ?) are more common or more fatal among soldiers serving at home than among civilians, the above figures show what a fatal disease pneumonia is, and how worthy of renewed study its causes are.

### 5. *The Class of Continued Fevers.*

The returns do not carefully distinguish the several forms, but practically the majority of the fatal cases of "continued fever" are from enteric (typhoid) fever.

There has been a great decline in this class of late. In the ten years (1837–46) the average admissions were 62, and the deaths 1·72 per 1000 of strength. In the eight years ending 1867, the admissions averaged 22, and the deaths ·5 per 1000 of strength. In 1871 there were only 80 cases of enteric fever and 22 deaths in the whole army of 87,000 men. In the four years ending 1875 the mean total deaths from continued fever were 0·37 per 1000, and they amounted to 4·4 per cent. of the total deaths.

This mortality is decidedly below that of the male civil population of the same age, which amounts to 9·6 per cent. of total deaths, and very nearly 1 per 1000 of population.

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* Monats-Bl. für Med. Stat. 1857, and Schmidt's Jahrb. 1862, No. 3, p. 337.

† Med. Statist. 2d edit. p. 567.

‡ Vacher. Sur la Mort. en 1865, Paris, 1866, p. 127.

§ In thirteen years there were 4826 cases treated, and 588 deaths, or 12·18 deaths per cent. In Canada, the deaths to admissions were only 7·13 deaths per cent. (average of twelve years ending 1870.)

During late years no points have been more attended to in the army than pure water supply and good sewerage, and we see the results in this very large diminution of deaths from the rate of the former period, and in the fact that in this particular class of disease the soldier is far better off than the civil population. So also the cholera of 1866 passed very lightly over the army at home (only 13 deaths out of 70,000 men), although in former epidemics the army suffered considerably.

The decline of enteric fevers confirms most strongly the doctrine of its intimate dependence on bad sewage arrangements.

The greatest amount of typhoid fevers in the army is in the garrisons in the seaports, the least in the camps.

The other classes of disease causing mortality need no comment. Chronic bronchitis is no doubt to be chiefly referred to phthisis (using that term as a generic word to include various disorganising lung diseases), and delirium tremens is a return which will, no doubt, gradually disappear.

The smaller items of mortality, making up 22 out of every 100 deaths, are various; erysipelas, pyæmia, syphilis, hepatitis (in men from foreign service), enteritis, rheumatism (from heart complication probably, but returned as rheumatism), diabetes, ebriositas, scarlet fever, and diphtheria, are a few of the many causes which carry off a small number every year. The cancerous and kidney diseases are very few, as we might expect from the age of the men.

To sum up the case as regards the present mortality on home service, it may be stated that for the last sixteen years (up to 1875) there has been some lessening, but no great fall in the number of deaths. There is still much to be done in respect of preventing disorganising lung disease, disease of the circulatory organs, and even fever, for we ought not to be satisfied until the term enteric fever is altogether obliterated. A renewed study of the causes of pneumonia is also necessary, in order to see if some way or other the attacks of that fatal disease cannot be lessened. There is no reason to think that we have yet touched the lowest possible limit of preventable disease; but, on the contrary, we can see clearly that the soldier, comparatively healthy as he is, may be made more healthy still. Some evidence in support of such a view may be found in the fact, that both at Gibraltar and in some of the West Indian stations the mortality has been lower in some years than it has ever been at home. But there is no reason why the home mortality should not be reduced to the standard of those foreign stations.

An important question now arises—Why, after thirty years of age, should the soldier die more rapidly than the civilian, though for the first ten years of his service he has a smaller mortality. The causes may be foreign service, bad social habits (*i.e.*, excess of drinking and syphilis, or other effects of enforced celibacy), night duty, exposure on guard, and prolonged influence of impure barrack air. But to which of these the result is owing could only be determined by accurate statistical inquiries of the causes of mortality at the older ages. We do not know these, and it is of no use to discuss a topic on which sufficient facts are not available.

### *B.* LOSS OF STRENGTH OF THE ARMY BY INVALIDING.

The amount of invaliding is influenced by other causes than mere inefficiency of the men; sometimes a reduction is made in the army, and the opportunity is taken to remove weakly men who would otherwise have continued to serve. This was the case in 1861. As invaliding greatly affects the mortality of the army, a source of fallacy is introduced which it is not easy to avoid.

During the seven years (1860–66), there were invalided every year nearly 37 men out of every 1000, thus making a total loss by death and invaliding from disease of nearly 46 men per 1000, or about one-twenty-second part of the whole force. In 1867 the invaliding was lower, viz., 22·18 per 1000.* The causes of the invaliding were very carefully ascertained by Dr Balfour, and inserted in his reports, and the work is continued under his successor. Speaking in round numbers, phthisis and scrofula account for about one-fourth of the invalids, and if chronic bronchitis is included, for nearly seven-twentieths, the two items of hypertrophia cordis and morbus valv. cord. account for one-tenth and chronic rheumatism for one-fourteenth. The three nervous diseases of amentia, mania, and epilepsy always cause a large number of invalids, amounting nearly to one-tenth, or almost the same as the two classes of heart diseases. All the other items are smaller. In men invalided under one year's service nearly one quarter are so from epilepsy; the remaining chief causes are phthisis and diseases of the circulatory organs. It is probable that the loss from invaliding will continue to diminish as a consequence of the short service system.

## SECTION II.

## LOSS OF SERVICE FROM SICKNESS PER 1000 PER ANNUM.

(*a*) *Number of Admissions into Hospital.*—On an average 1000 soldiers furnish rather under 1000 admissions into hospital per annum; 833·5 in ten years (1865–74). The number varies in the different arms from about 600 in the Household Cavalry, which is usually the lowest, to about 1100 in the Cavalry and Artillery Depôts. In the first case the steady character of the men, many of whom are married, and in the second the frequency of contusions during drill, accounts for this great range. In the Infantry the average is from 850 to 1020. In 1875 the highest was 1232 in a battalion of the Guards, and the lowest 422 in a line regiment just returned from the Cape: the mean was 752.

The number of admissions remained tolerably constant for twenty-five years, but during late years has been sensibly declining.

The admissions in the French army are not comparable with ours; slight cases of sickness (which with us are often not recorded) are treated in barracks (*à la chambre*), severer, but still slight, cases in the infirmaries, bad cases in the general hospitals. The mean of five years (1862–66) gives 2028 total admissions per 1000 "present." The admissions to the infirmaries in France (in 1866) were 323 per 1000 "present;" to the hospitals, 306; making a total of the severer cases of only 629 per 1000 in that year. This shows how many slight cases there are in the French army. In the eight years (1862–69) the mean number of slight cases in France was 1745 per 1000 (Morache).

In the Prussian army the average admissions (mean of 18 years, 1846–63) were 1336. In 1867 there were 1125·6 per 1000. In 1873–75 it was 750, and in 1876 only 620 (Roth).

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* In ten years, from 1865–74 the mean number invalided was 22·21 per 1000 of the whole army, and 27·39 of the troops in the United Kingdom, making with deaths a loss for the whole army of 36·71, and for the United Kingdom 36·45 per 1000. The numbers for 1875 were below the average; viz., invalided from the whole army 19·80, from the United Kingdom 25·80, or, respectively, with deaths, a loss of 32·27 and 35·16. This is only about $\frac{1}{31}$th to $\frac{1}{28}$th of the force.

(*b*) *Daily number of Sick in Hospital per* 1000 *of Strength.*—About one-twenty-fifth of the army (average of ten years, 1865–74) is constantly sick in time of peace, or 4 per cent.

It is not possible to compare the army sickness with the civil population, or even with other armies.

In England, the number of members of friendly societies, between twenty and thirty years of age, who are constantly sick is nearly 16 per 1000.

In the French army, the mean sick in hospital are 29 per 1000 present; in both hospital and infirmary, 50; in the Prussian, 44 (in 1876 only 25·5); in the Austrian, 45; in the Belgian (1859), 54·2; in the Portugese (1851–53), 39·4.

The number of daily sick has, of course, a wide range; sometimes an hospital is almost closed, at other times there may be more than 100 sick per 1000 of strength.

(*c*) *Number of Days spent in Hospital per head in each* 1000 *of Strength.*—The number of days' service of a battalion 1000 strong in a year would be of course (1000 × 365 =) 365,000. If we assume the average number of sick to be 40½ per 1000, there are lost to the State (40½ × 365 =) 14,782 days' service per annum, or 14¾ days per man. As already said, it is difficult to compare the sickness of soldiers and civilians, but the above amount seems large when we remember that, in the friendly societies, the average sickness per man per annum (under forty years of age) is less than seven days.

*Mean Duration of Cases of Illness.*—The number of days each sick man is in hospital (mean duration of cases) is rather greater (17·8) as the number of admissions is below the strength.

It can be most easily calculated as follows: multiply the mean daily number of sick (sick population) by the number of days in the period, and divide by the cases treated. The number of "cases treated" is the mean of the admissions and discharges in the period.

Austrian army, 17 to 18 days.
French at home, all cases (1862–66), 7·97 days.
French in hospitals only (1862–66), 26·3 days.
French in infirmary, 12 days.
French *à la chambre*, 3·10 days.
Prussian (1859–63), in hospitals, 18·9 days.
Belgian, 23·6 days.
Portuguese, 19 days.

(*a*) *Mortality to Sickness.*—This is, of course, a different point from that of the relation of mortality to strength. A few cases of very fatal illness may give a large mortality to cases of sickness, but the mortality to strength may be very small.

The mere statement of the ratio of mortality to sickness gives little information; what is wanted is the mortality of each disease, and at every age. Otherwise the introduction of a number of trifling cases of disease may completely mask the real facts.

When, however, the general ratio is to be determined, it must be calculated in one of three ways:—

1. Mortality to admissions in the time. This is, however, an uncertain plan; a number of cases admitted towards the close of a period, and the greater part of whose treatment and mortality falls into the next period, may cause an error.

2. Mortality to cases treated (= mean of admissions and discharges).* This is the best method of calculation.

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* It has not infrequently happened that the mortality on sickness has been calculated in this way; the number of sick remaining in hospital at the commencement of the period, say a year,

3. Mortality to sick population, *i.e.*, the number of deaths furnished per annum by a daily constant number of sick. This, however, must be taken in connection with the absolute number of sick in the time, and with the duration of the cases, or, in other words, with the kind of cases.

The degree of mortality to the several causes of sickness was given very fully in the Army Statistical Reports, up to the year 1873, since which time the detailed returns have been discontinued.

Calculated on the admissions, the mortality to total sickness in the English army at home is a little above the mortality to strength, or about 11·3 per 1000 per annum (1865–74). In the Prussian army it was 7·25 (years 1846–62); in 1872 it was 7·7.[*]

### CAUSES OF SICKNESS.

The causes leading men to go into hospital are, of course, very different from those which produce mortality. For example, admissions from phthisis will be few, mortality great; admissions from skin diseases numerous, mortality trifling.

Taking the most common causes of admission in the order of frequency, we find—

1. *Venereal Diseases* (see page 500).—Under the term Venereal, all diseases, immediate or remote, resulting from sexual intercourse, are included. Secondary as well as primary syphilis; stricture and orchitis, as well as gonorrhœa, &c.; also a few cases not strictly venereal. The primary venereal forms are, however, of the most importance.

At p. 506 will be found tables showing the admissions from primary venereal sores and gonorrhœa. In stations under the Contagious Diseases Act, 1000 men give 33 admissions from the former and 68 from the latter. In stations not under the Act, the amount of gonorrhœa is 30 per cent. higher, and syphilis is more than double. There are other admissions from secondary and tertiary syphilis, which somewhat increase the total admissions.

We have no certain facts with which we can compare the syphilitic disease of the civil population with that of the army. The amount among the civil population at large is really a matter of conjecture. But whether it is greater or less than that of the army does not affect the result drawn from the above figures, viz., that there is an appalling loss of service every year from the immediate or remote effects of venereal disease.[†]

It should be understood, also, that the action of syphilis is long continued. Many soldiers die at Netley[‡] from various diseases, whose real affection has been syphilis, so that the influence of this cause is very imperfectly indicated

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are added to the admissions in the year, and the mortality is calculated on this number. At the end of the year a certain number of sick remaining in hospital are carried on to the next year, and added to the admissions of that second year for the calculation of the mortality of that year. In this way they are counted twice. This has been done in calculations of weekly mortality, and in this way the same sick man has been made to do duty as a fresh case many times over. This is to be avoided by either calculating on the admissions, or by considering half the "remaining" at the beginning to belong to the previous period, and half the "remaining" at the end of the period to belong to the following period; or, what is the same thing, taking half the admissions and half the discharges in the period as representing the "cases treated" in that time.

[*] For numerous statistical details of foreign armies see Roth and Lex, *op. cit.* vol. iii. p. 411 *et seq.*

[†] The order issued in 1873, directing stoppages to be made from men in Hospital affected with venereal disease, was a most unfortunate one, as giving every inducement for the concealment of disease.

[‡] My colleagues, Professors Maclean and Aitken, are both very much impressed with the frequent occurrence of marks of continued and dominant syphilitic action in the bodies of men who die from what are considered other diseases.

by the number of admissions and service lost under the head of enthetic

*General Diseases.*—The important diseases included under this class give one-fourth of the total admissions, or about 205 per 1000 (1869–74).

(*a*) Eruptive fevers are not very common, about 3 per 1000. Smallpox is checked by vaccination; measles and scarlatina are not frequent.

(*b*) Paroxysmal fevers (many of which have been contracted out of England), give about 11 per 1000.

(*c*) The continued fevers are more common, but their frequency is lessening. There is no doubt that typhoid is the chief, perhaps almost the only fever besides febricula which is now seen. Spotted typhus is at present uncommon. The continued fevers cause about 22 admissions per 1000 of strength. In 1866 there was only 15 admissions per 1000. During the last few years there have been some cases of cerebro-spinal meningitis.

(*d*) Rheumatism gives 50, dysentery and diarrhœa 25, sore throat and influenza 50, and ophthalmia 20 to 25 cases per 1000 of strength. All these diseases are declining in frequency.

3. *Integumentary diseases* usually give the next greatest number of admissions—viz., from 100 to 130 (97·6 in 1869–74). This does not include scabies, but is made up of a great number of cases returned as phlegmon and ulcers (which appear to be rather more common among the cavalry and artillery), and a much smaller number of cases of eczema, herpes, psoriasis, and impetigo.

4. Diseases of the *respiratory* organs (excluding tuberculosis) give the next largest number—viz., from 75 to 110 per 1000, the mean being nearly 82 for 1869–74. Of the 100 cases acute bronchitis gives 66·5 per cent.; chronic bronchitis 16·5; and pneumonia and pleurisy each 8·5 per cent. (nearly).

5. *Accidents* follow with from 70 to 100 admissions per 1000 of strength. Contusions are much more common in some regiments than in others, especially in the artillery and cavalry depôts, where recruits are in training.

6. Diseases of the *digestive* system cause about 100 admissions; dyspepsia is the chief heading; then chronic hepatitis (although it is very questionable if this term is not a conventionalism), and hæmorrhoids.

7. *Parasitic* diseases come next, with an average of about 30 or 40 cases per 1000; which are made up of scabies, and a smaller amount of "porrigo."

8. Diseases of the *nervous* system give about 15 to 20 per 1000. Epilepsy gives the largest number; then otitis; then cephalæa.

9. *Tubercular* diseases cause about 18 admissions per 1000.

10. Diseases of the *reproductive* (*venereal* excluded), *locomotive*, and *urinary* systems, give 6, 3½, and 3 admissions per 1000 of strength.

11. The remaining admissions are made up of smaller classes.

Can the causes of any of these admissions into hospital be lessened or removed? On this point there is no room for doubt that the venereal admissions could be greatly lessened; so also could the admissions from fever, which have in fact been already reduced from 60 to 22 per 1000 of strength. The large class of integumentary diseases would probably admit of reduction. What is the exact nature of the phlegmon and ulcers which form so large a proportion of the admissions? Trifling as the cases are, they form a large aggregate, and a careful study of their mode of production might show how they might be diminished. Probably, however, these are mere conventional terms, under which a number of trifling cases are conveniently recorded, but a complete analysis of the returns, of one year under phlegmon would be desirable. So also of all the other classes, it may be concluded that an active medical officer might succeed in reducing the cases of rheumatism, bronchitis, and dyspepsia.* Many cases of acute respiratory diseases are produced by exposure on guard, especially by the passage into and from the hot close air of the guard-room to the open air on sentry duty. Good additional overcoats, means of drying the clothes, and proper ventilation of the guard-rooms, would probably lessen the cases of bronchitis and pleurisy.

*Sickness in Military Prisons.*—The admissions into hospital in the military prisons do not appear to be great; they have varied per 1000 of admissions of prisoners from 316 (in 1851) to 725·5 in 1863.† Calculated in the mean strength, the result is as follows:—In 1863, the daily average number of prisoners were 1064; the admissions for sickness, 722; the mean daily sick, 21; the mortality, 0. These numbers give 725·5 admissions, and 19·74 mean daily sick per 1000 of strength. Prisoners are healthier than their comrades at duty in the same garrisons where the prisoners are under sentence.

## SECTION III.

Such, then, being the amount of mortality and sickness at home, it may be concluded that the soldier at present is not yet in so good a condition of physical health as he might be; and we can confidently look to future years as likely to show a continuance in the improvement now going on. In future years, however, the new system of limited service will render it difficult to trace the progress in the infantry.

Health is so inextricably blended with all actions of the body and mind, that the medical officers must consider not only all physical but all mental and moral causes acting on the men under their charge.

The amount of work, the time it occupies, its relation to the quantity of food, the degree of exhaustion it produces, the number of nights in bed, and other points of the like kind; the mental influences interesting the soldier, or depressing him from *ennui*; the moral effect of cheerfulness, hope, discontent and despondency upon his health, as well as the supply of water, air, food, clothing, &c., must be taken into account. And just as the body is ministered to in all these ways, so should there be ministration of the mind. It is but a partial view which looks only to the body in seeking to improve health; the moral conditions are not less important; without contentment, satisfaction, cheerfulness, and hope, there is no health.

Hygiene, indeed, should aim at something more than bodily health, and should indicate how the mental and moral qualities, essential to the particular calling of the man, can be best developed.

How is a soldier to be made not merely healthy and vigorous, but courageous, hopeful, and enduring? How, in fact, can we best cultivate those martial qualities which fit him to endure the hardships, vicissitudes, and dangers of a career so chequered and perilous?

Without attempting to analyse the complex quality called courage—a quality arising from a sense of duty, or love of emulation, or fear of shame, or from physical hardihood, springing from familiarity with and contempt of danger,—it may well be believed that it is capable of being lessened or increased. In modern armies, there is not only little attempt to cultivate courage and self-reliance, but the custom of acting together in masses, and of dependence on others, actually lessens this. It is, then, a problem of great interest to the soldier to know what mental, moral, and physical means must be used to strengthen the martial qualities of boldness and fortitude.

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* It is right, however, to say that no medical officer ought to sacrifice his men in the slightest degree for the purpose of appearing to have a small sick list and an empty hospital. There is a temptation in that direction which we have to guard against, and to remember that the only question to be asked is, What is the best for the men? not, What will make the best appearance?

† Report on Prisons for 1863, p. 24.

The English army has never been accused of want of courage, and the idea of pusillanimity would seem impossible to the race. But drunkenness and debauchery strike at the very roots of courage; and no army ever showed the highest amount of martial qualities when it permitted these two vices to prevail.* In the army of Marlborough, the best governed army we ever had, and the most uniformly successful, we are told that the "sot and the drunkard were the objects of scorn." To make an army perfectly brave, it must be made temperate and chaste.

Good health and physical strength, by increasing self-confidence, increase courage; and self-reliance is the consequence of feeling that, under all circumstances, we can face the dangers and difficulties that present themselves.

Few wiser words were ever written than those by William Fergusson,† at the close of his long and eventful service.

"Of the soldier's life within these barracks," writes Fergusson, "there is much to be said, and much to be amended. To take his guards, to cleanse his arms, and attend parade, seems to comprehend the sum total of his existence; amusement, instruction beyond the drill, military labour, and extension of exercises, would appear, until very recently, to be unthought of; as it is impossible that the above duties can fully occupy his time, the irksomeness of idleness, that most intolerable of all miseries, must soon overtake him, and he will be driven to the canteen or the gin-shop for relief.

"Labour in every shape seems to have been strictly interdicted to the soldier, as water for his drink. All, or nearly all, must have been bred to some trade or other before they became soldiers; but they are work for them no longer. Labour (the labour of field-works and fortifications) strengthens the limbs and hardens the constitution, but that is never thought of in our military life at home; so thought not the ancient Romans, whose military highways still exist, and who never permitted their soldiers to grow enervated in idleness during peace. Better, surely, would it be that every one should work at his own craft, or be employed on the public works, in regulated wholesome labour, than thus to spend his time in sloth and drunkenness. But his exercises, without even going beyond the barrack premises, may be made manifold—running, wrestling, gymnastic games of every kind, swimming, leaping, pitching the bar, the sword exercise (that of the artillery), all that hardens the muscles and strengthens the limbs, should be encouraged; and when the weather forbids out-door pastimes, the healthy exercise of single-stick, in giving balance and power to the body, quickness to the eye, and vigour to the arm, may properly be taken as a substitute for the drill which, after the soldier has been perfected in his exercise, is always felt to be a punishment. So is the unmeaning evening parade and perpetual roll-calling.

"Foot-racing too, the art of running, so little practised, and so supremely useful, should be held amongst the qualities that constitute military excellence.

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* There are many sober and excellent men in the army. But as a rule, the English soldier cannot be depended upon under any circumstances, if he can get drink. Well does Sir Ranald Martin, say, "Before that terrible vice can be overcome, something far more powerful than medical reasoning on facts, or the warnings of experience founded on them, must be brought into active operation. Discipline must still further alter its direction:—in place of being active only to punish wrong, it ought and must be exerted further and further in the encouragement to good conduct."—*Ranald Martin*, "*Tropical Climates*," p. 263.

† Notes and Recollections of Professional Life, 1846, p. 49.

It was so held at the Isthmian games of ancient Greece, and deserves a better place than has hitherto been assigned to it in the military pastimes of modern Britain. In our school-books we are told that the youth of ancient Persia were taught to launch the javelin, to ride the war-horse, and to speak the truth. Let the young British warrior be taught to use his limbs, to fire ball-cartridge, to cook his provisions, and *to drink water*. The tuition may be less classical, but it will stand him in far better stead during every service, whether at home or abroad.

"Regular bodily pleasurable exercise has been said to be worth a host of physicians for preserving military health; and occupation without distress or fatigue is happiness. The philosopher can make no more of it; and every idle hour is an hour of irksomeness, and every idle man is, and must be, a vicious man, and to a certain extent an unhealthy one."

In many of the foreign stations of the British army, excellent opportunities exist for both occupying the men and developing their spirit. All history teaches us that a hunting race is a martial one. The remarkable fighting qualities of the English, as drawn in Froissart's "Chronicles," were owing to the fact that at that time they were "a nation of hunters," and trained from infancy to face dangers alone. In India there are many places where men could not only be allowed to hunt, but where such permission would be the greatest boon to the inhabitants.

The English army has hitherto offered but few incentives to good conduct, and scanty encouragement for the cultivation of martial qualities. Men must have rewards, and feel that earnest endeavour on their part to become in all respects better soldiers is neither overlooked nor unrewarded. The new order of things introduced by Lord Cardwell seems likely to open up means of progress for men who can acquire knowledge and to deserve advancement.

The cultivation of the martial qualities of the soldier is in reality a part of hygiene considered in its largest sense, but this part of hygiene must be studied and carried into effect by the combatant officers. Let us trust it may not be long before they seriously study and endeavour, by precept and example, to promote the formation of those habits of boldness and endurance, and that fertility in resources, which are as necessary as technical knowledge to render an army the formidable instrument it is capable of becoming.

# CHAPTER IV.

# FOREIGN SERVICE.

The foreign service of the British army is performed in every part of the world, and in almost every latitude, and probably more than two-thirds of each line soldier's service is passed abroad. The mere enumeration of the stations is a long task; the description of them would demand a large volume. In this short chapter, to give a few general statements as to climate and geology, and the past and present medical history of the stations, only can be attempted; such an outline as may give medical officers a sort of brief summary of what seems most important to be known.

Detailed and excellent accounts of most of the foreign stations exist, either in the independent works of army surgeons, such as those of Marshall, Hennen, Davy, and many others, or in reports drawn up for Government, and published by them. In the early Statistical Reports of the Medical Department of the army, short topographical notices of the stations were inserted; they are models of what such reports should be, and must have been drawn up by a master in the art of condensation. In the Annual Reports now published, many excellent topographical descriptions will be found; and some of the Indian Governments have published complete descriptions of all their stations. In the "Bombay Transactions," the "Madras Medical Journal," and the "Bengal Indian Annals," are very full accounts of almost every station that has been, or is, occupied by European troops in India. Finally, in the "Indian Sanitary Report" is much important information on the meteorology and topography of the present Indian stations. Young medical officers first entering on foreign service are strongly advised to study these accounts of the stations in the command where they are serving; it will not only give them interest in their service, but will aid them in their search how best to meet the climatic or sanitary conditions which affect the health of the men under their charge.

## SECTION I.

## MEDITERRANEAN STATIONS.*

### GIBRALTAR.

Usual peace garrison = 4500 to 6000 men. Period of service, three years. Civil population = 18,695 (in 1876). Height of rock, 1439 feet at highest point. Nature of rock, grey limestone, with many cavities filled with reddish clay; under town, an absorbent red earth forms the subsoil.

*Climate.*—Mean temperature of year = 64·1;† hottest month, August (invariably in eight years) = 76·6; coldest month, either January or February, in equal proportions, 53·77; amplitude of the yearly fluctuation, 22·83 (= difference between hottest and coldest months).

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* A very important Report on the Mediterranean Stations has been published by the Barrack Improvement Commissioners (Dr Sutherland and Captain Galton).—*Blue Book*, 1863.

† Mean of eight years' observations by the Royal Engineers (1853–60), as given in the Barrack Commissioners' Blue Book (1863). The numbers given by Dove are rather different, viz., mean of year 66°. Hottest month, July, 79°·5. Coldest month, February, 56°·6. Mean yearly range, 22°·9. Extreme yearly range, about 50°.

Mean monthly maximum and minimum in shade*—hottest month, July or August—mean maximum = 89; coldest month, December, January, or February—mean minimum, 42°. Range of highest and lowest monthly means of maximum and minimum, 47°. Extreme yearly range (difference between highest and lowest temperature recorded in the time) about 50° to 58°. The minimum thermometer on grass sometimes falls to 4° or 6° below freezing.

*Rainfall.*—Mean 32·8 inches (mean of seventy years, 1790–1860). Greatest amount in any one year, 75·8 (1855). Least amount in any one year, 15·1 (1800). The importance of this great variation, as regards sieges, is evident; Gibraltar might be embarrassed for water, if the rainfall were only 15 inches in a year of siege.

*Number of Rainy Days* = 68. The rain is therefore infrequent, but heavy. The rain falls in nine months, September to May; greatest amount in January and November; most rainy days in April. Summer, rainless.

*Humidity.*

| | Dew-point. | Grains of Vapour in a cubic foot. | Relative Humidity Sat. = 100. |
|---|---|---|---|
| Mean dew-point of year, | 55°·9 | 5·75 | 72·3 |
| Mean highest dew-point in August, . . . | 67°·9 | 7·5 | 70·9 |
| Lowest dew-point in January or February, . . | 43°·5 | 3·25 | 69·1 |

Gibraltar is thus seen to be rather a dry climate; at any rate, the air is on an average only three parts saturated with moisture, and therefore evaporation from the skin and lungs will be tolerably rapid, provided the wind moves freely. It is certainly not a moist insular climate, as might have been anticipated. At the times of rain, however, and during fogs and moist sirocco, the air is nearly saturated.

*Winds.*—Chiefly to the N.W. or S.W. or W., in January, April, May, June, and October. Easterly in July, August, and September. But sometimes the easterly winds are more prevalent, or may be moderate for almost the whole year. The east and south-east winds are sirocco (Levanteros), and are often accompanied by rain and fogs.

### *Sanitary Conditions.*

*Water Supply.*—The *quantity* was formerly very deficient; in 1861 only 2½ gallons daily were supplied for non-commissioned officers and privates.

*Sources.*—Wells and tanks, rain water, and a small aqueduct carrying surface water. Very large tanks have been constructed in two of the ravines, with arrangements for passing into them a large amount of surface water; and lately fresh wells have been dug at the north end, near the neutral ground, which yield a large supply of good water.

*Quality.*—In a well from the neutral ground analysed by Mr Abel, there was much calcium sulphate and nitrate (4·5 and 6 grains per gallon), and calcium carbonate (12 grains per gallon), also alkaline chlorides (7 or 8 grains).

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* Of the eight years (1853–60) given in the report above quoted, the difference between the monthly mean maximum and minimum is so much less in the last three years, as to make one suspect some error in observation. In 1875 the mean maximum in August was 87·4, the mean minimum in January 51°4—range 36°; absolute maximum 91° in August, absolute minimum, 42 in January—range 49°.

and 4 grains of organic matter.* A tank water contained less lime, but much magnesium carbonate. A well water in the town contained no less than 39·6 grains of calcium nitrate, and 15 grains of calcium sulphate, per gallon. The immense amount of nitric acid points unequivocally to the oxidation of animal organic matter. The tank water is good when filtered; but the tanks require frequent inspection and cleaning.

Many of the houses of the civilians have tanks, and no new house is allowed to be built without a tank. The distribution of water, both to soldiers and civilians, is defective; it is almost entirely by hand.

*Drainage.*—The sewers are at present being much improved. A new outfall near Rosina Bay has been made, and the whole system of sewage will soon be in fair order.†

*Barracks.*—More than half the garrison is in casemates, which have been described as "mere receptacles of foul air, damp, dark, and unwholesome."‡ The barracks are, for the most part, badly arranged, and are overcrowded; the average cubic space in 1862 was only about 450 feet, and the average superficial space under 40. Ventilation was very defective, especially in the casemates. In all those points, however, great improvement has taken place. The means of ablution are defective. Latrines and urinals are also defective.§ The duties are not heavy, and the rations are said to be good. In 1860 some improvements were made in the dress of the troops, and a light summer suit ordered. Flannel next the skin has been recommended strongly for Gibraltar on account of the occasional cold winds.

### *Health of the Civil Population.*

Gibraltar is now a place of considerable trade; whether the Government have been right in allowing a mass of people to herd closely together in the midst of the most important fortress we possess, is very questionable. In case of a siege they would be a serious embarrassment, and even in time of peace they are objectionable. The health of this community is bad; in 1860, the northern district, where population is densest, gave 38 deaths per 1000, or, excluding cholera, 33·5; in the more thinly populated southern end, the mortality was 27·5 per 1000, or more than St Giles', in London. The deaths in children under one year form 17·33 per cent. of the total mortality. The prevailing causes of this mortality are fevers (in all probability typhoid), and tuberculous consumption, which causes 13 per cent. of the total deaths at all ages, or 37·6 per cent. of the total deaths at the soldiers' ages. Dysentery and diarrhœa are common.

In this compressed and dirty population several great epidemics have occurred. The bubo plague does not appear to have been seen since 1649, but the earlier records are very imperfect; yellow fever, however, prevailed in 1804, 1810, 1813, and 1828. Cholera has prevailed several times; the last time was in 1865.

## HEALTH OF THE TROOPS.

### *Loss of Strength by Death and Invaliding.*

(*a*) *By Death.*—Gibraltar has never suffered from any great sickness or mortality, except in yellow fever or cholera years. At the time when the mortality, on home service was 17 or 18 per 1000 of strength, it was usually not more than 12 at Gibraltar. Of late years both sickness and mortality has been below that of home service, especially in the latter years. In spite of this comparative healthiness, it is quite certain that much preventable disease existed, and in part still exists on the Rock.

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* Samples from the wells on the neutral ground, recently analysed at Netley, showed a great quantity of chlorides and excessive hardness. There was but little organic matter.

† It is probably completed by this time.

‡ Barrack Commissioners' Report, p. 37.

§ All these points are noted in the Barrack Commissioners' Report, and are in process of alteration; they are merely referred to here as bearing on the question of the amount and prevention of disease. Plans of all the proposed improvements are given in the Commissioners' Report.

*Mortality per 1000 of Strength.*

| Years. | Total Deaths. | Deaths from Disease alone. |
|---|---|---|
| 1837–46 (10 years), . . . . . | 12·9 | 5·65 |
| 1861–70 (10 years),* . . . . | 8·54 | |
| 1871, . . . . . . . | 5·87 | |
| 1875, . . . . . . . | 5·50 | |

The last years are placed by themselves to show what low mortality is possible among soldiers, and what in all probability may be the usual amount in future years.†

*Causes of Death.*—In the earlier years the chief causes of death were phthisis and continued fever, which was doubtless enteric fever. Of late years phthisis has declined; enteric fever, on the contrary, increased up to 1863, has since then declined in frequency, though not in fatality per cent. of attacked. By expressing the facts as per cent. of deaths, the relation will be seen clearly—

*In 100 Deaths from all Causes.*

| Years. | Phthisis. | Continued (Enteric Fever chiefly). | Head Affections, Delirium Tremens included. |
|---|---|---|---|
| 1837–46, . . . | 41 | 17·65 | 9·28 |
| 1863–66, . . . . | 16·84 | 28·94 | |
| 1867, . . . | 22·75 | 11·44 | |
| 1875, . . . | 23·10 | 23·10 | |

Instead of expressing the facts in this way, they may be put in another form. The admissions from phthisis averaged 11 per 1000 of strength in the ten years, 1837–46, while in the eight years, 1859–66, they were only 7·63. In the years 1863–66 the deaths and invaliding together from phthisis were only 3·72 per 1000 of strength, or hardly more than the deaths alone at home. The decline in phthisis seems therefore certain, and the diminution has since continued, but still it is possible that it is not even now so low as it might be.

The continued fevers gave 75·5 admissions per 1000 of strength in the years 1837–46, and 98·5 in the five years ending 1863. There was also an increase in mortality. In the three years ending 1866 the admissions fell to an average of 42, and the decline was progressive. In 1867 there was an increase in admissions, owing to the prevalence of a mild fever very like the dengue of the West Indies. In 1871 there were 7 deaths from enteric fever, while there were only 26 deaths in all.‡

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* Cholera prevailed in 1865, and raised the mortality to 23·74. Without cholera it was 7·91.

† Of course invaliding has an effect, but the invalids who died at Netley are included in the above numbers.

Even this mortality is more than is necessary. In 1866 there were 15 deaths out of 4565 men. Of these, 3 from typhoid, and therefore preventable, 4 from phthisis, 2 from apoplexy, 3 from heart disease, 1 from aortic aneurism, 1 from asthma, and one from violence. The immense relative amount of disease of the circulatory organs is striking; it formed 26·6 per cent. of total deaths; and in each of the three preceding years there had been 3 deaths under the same headings.

‡ Admissions have increased in the last few years, the mean being 64·9 per 1000, for the five years 1869–74.

During the last few years, much has been done in Gibraltar to give the men more breathing space and ventilation, hence the decline in phthisis which was so fatal formerly when the men were crowded in casemates. When their barracks are still further improved, we shall see a still greater lessening of phthisis. The water supply has also been better looked after, and efficient drainage has been commenced, and is now nearly completed.

The prevalence of heart diseases is a striking circumstance, and I cannot but believe is caused by the same conditions as at home.

The habits of the men are much improved, and delirium tremens, formerly common, is rare. In 1865 and 1866 only one man died in two years from this cause, or at the rate of scarcely more than ·1 per 1000 of strength.

Formerly dysentery and diarrhœa were common; now they are infrequent and mild. The average admissions from dysentery in three years (1864–66) were only 2 per 1000; in 1864 and 1866, from diarrhœa were only 12 per 1000.*

Everything points to the fact that Gibraltar itself is a perfectly healthy place, and, that when the sanitary alterations now going on are completed, the sickness and mortality will be trifling.

The influence of age on mortality is not given separately for Gibraltar, and is included in a subsequent table.

(*b*) *By Invaliding.*—The number of men sent home for change of air and discharge varies greatly from year to year; about 20 to 30 per 1000 of strength is the average. The chief diseases are ophthalmia, phthisis, syphilis, and cardiac disease. The other diseases are in smaller number, but are numerous. Dysentery and liver diseases used to be common causes of invaliding, but both are now declining.

## 2. *Loss of Service by Sickness.*

The admissions, the mean daily sick, and the duration of the cases, are all below the home standard.

*Per* 1000 *of Strength.*

| YEARS. | Admissions per Annum. | Mean daily Sick. | Mean Stay in Hospital of each Sick Man in days. |
|---|---|---|---|
| 1837–56, . | 976 | ... | ... |
| 1861–70, . | 742 | 36·57 | 18·39 |
| 1865–74, . | 656·6 | 32·61 | 18·18 |
| 1875, . . | 620·9 | 38·36 | 22·55 |

The venereal diseases cause fewer admissions than at home; the average of the whole venereal class is only about 120 per 1000. For syphilis alone the average (1869–74) is only 51·8. This is owing to the police regulation of prostitutes. Integumentary diseases cause about 65 admissions per 1000. "Continued fevers" caused 64·9 (1869–74), and in 1875, 90·5 admissions. Dysentery and diarrhœa are now declining from the former average of 58 to 20 or 30 per 1000. Digestive disorders give a large number of admissions, and have always done so, but in the latest returns they are somewhat declining.

*Sanitary Duties at Gibraltar.*—Captain Galton and Dr Sutherland have already indicated the measures which must be adopted, viz., a better supply of water, by arranging a larger storage; a better drainage, with sea water for flushing, and a different outlet; and an improved ventilation, with less crowding in barracks. All the plans are being gradually carried out. There is no doubt these measures will greatly improve health.

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* Cholera prevailed in 1865, so I have left that year out.

It may be suggested whether, as water is so deficient, a removal of sewage by hand might not be employed. The soil might be used for cultivation in the neighbourhood of the Rock, or carried out to sea.

Supposing war were to arise at this moment, and that we lost the command of the sea for a time, the points of danger would apparently be these:—

1. *Deficient Water, the Rainfall being uncertain.*—The new wells near the neutral ground will perhaps obviate this danger; but if not, it would have to be supplied by distillation, and it would be prudent to keep a good apparatus always at Gibraltar. The amount of storage has been increased of late years.

2. *Overcrowding and Bad Ventilation, leading to Spotted Typhus.*—With a full garrison, and with some barracks untenable, there is no doubt there would be serious danger of this disease; and it is a matter of great moment to ventilate as perfectly as possible all casemates which, even if now disused, must be used in time of war.

3. *Typhoid Fever.*—The drainage is now being improved, so that this cause of danger may soon be entirely removed.

4. *Diseases arising in the Town, and spreading to the Garrison.*—In case of war, it would seem most desirable to clear out the native town as far as it can be done. More space and more water would be available. There would be less chance of famine, destitution, and disease.

In the war in 1792, scurvy prevailed from deficiency of food and fresh vegetables.

## MALTA.

Size, 17 miles by 8. Usual peace garrison = 5000 to 7000; period of service, three years; population (civil) in 1876 = 149,270.

*Geology.*—Soft, porous rock; the greater part is sandstone resting on hard limestone; in some parts there is marl and coral limestone over the sandstone. In the centre of the island, at Citta-Vecchia, there is, in order from the surface, alluvium, upper limestone, red sand, marl, sandstone, and lower limestone. Valetta is on thin alluvium, with thick sandstone below, and beneath this the lower limestone.

*Climate (at Valetta).*—Mean of the year, 68°; hottest month (July), 77°; coldest (January), 57°; amplitude of the yearly fluctuation, 20°; extreme yearly range (from highest to lowest temperature in shade), 62°, from 100° in July to 39° in January; mean yearly range, about 50°; extreme monthly range (*i.e.*, from highest to lowest in month), about 25° to 35.°

Undulations of temperature are frequent, and there are often cold winds in winter from N.W. The south-east wind is an oppressive sirocco, raising the temperature to 94° or 95°. It is chiefly in the autumn, and blows for from 60 to 80 days every year. At Citta-Vecchia (600 feet above the sea) the temperature is lower and the air keener. Rainfall about 32 inches. Chief rain in November, December, and January; less in February and March; small in amount in the other months. From June to August almost rainless.

*Humidity.*—(Mean of 1859–60); observations at 9.30 A.M. and 3.30 P.M.

| | Dew-point. | Grains of Vapour in a cubic foot. | Relative Humidity. |
|---|---|---|---|
| Mean of year, . . . | 60·5 | 5·87 | 62 |
| Highest in year (August), . | 72·7 | 8·73 | ... |
| Lowest in year (February), . | 49 | 3·96 | ... |

Malta thus appears to be a dry climate, *i.e.*, with little relative humidity.

### *Sanitary Condition.*

Much has been done of late years, and, as far as external cleanliness goes, Valetta is very clean. Water supply from rain and springs (the largest of which is in the centre of the island, and the waters of which are led by aqueduct), is not very deficient in quantity (8 to 10 gallons per head), and, except in some places, good in quality, though the rain-water contains chlorides from the spray falling on the roofs of buildings. Some of the tanks are too near the sea, which percolates into them. The tanks require, however, careful looking after. Within the lines there are 272 public and military tanks, with storage for 55 millions of gallons, and 4294 private tanks, with storage for 323 millions of gallons. The military tanks, if full, would give 6 gallons of water per man daily for eleven months, but even now the water often falls short. The water is carried everywhere by hand, and the drinking water for the men is not filtered, or only partially so. An attempt to get water by sinking into the sandstone was made in 1866–67, but failed. The sewers in Valetta are bad in construction and outlet, and much typhoid has been, and is still, caused in consequence. In many cases "they are nothing but long cesspoools."* Pipe drains are, however, now being laid in the old drains, which were merely narrow deep channels cut in the soft porous rock. The old style of drain has now quite ceased to exist in the barracks.

The barracks are bad, many casemates being used, and buildings which were intended for stores and not for habitations. They are built of soft sandstone, which both crumbles and absorbs wet. In some cases, all sanitary considerations have been sacrificed for the purposes of defence. The ventilation of the casemates is very bad, but some improvements have taken place. The Barrack Commissioners, in their Report, recommended that in every way which can be done the ventilation should be improved by admitting the wind, especially from the north, and that each barrack will require a separate plan to meet the particular case. They recommend that air shafts shall be made, much larger than ordered for home service, viz., 1 square inch for every 20 cubic feet of space, or for a barrack of twelve men with regulation space (7200 × 20 = ) 360 square inches ( = 2½ square feet) of outlet opening. Some of those points have been carried out with very good results. At the present time the amount of cubic space is below the home service amount (600 cubic feet), and the superficial area is very small, in some cases being as low as 40 square feet per head. All the barracks are now supplied with new and remodelled married quarters, with proper appliances.

A gymnasium is provided both in Cottonera and Valetta, and all the barracks are well provided with reading, recreation, and school rooms. The means of ablution are now very good in all the barracks, and there are new water latrines and slate or earthenware urinals provided.

We may therefore hope that a diminished amount of disease may be the result of these improvements, although much remains to be done to make the condition of the troops as good as it ought to be.

### *Health of the Civil Population.*

There is some, but no great amount, of malarious disease, but a good deal of the so-called bilious remittent,† and typhoid. Typhus is not at present seen. Bubo plague has prevailed seven times, the last in 1841, slightly. Yellow fever has been known, but not of late years. Cholera has occurred

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[*] Barrack Commissioners' Report, p. 111.

[†] See Dr Marston's excellent Report in the Army Medical Report for 1861, for the symptoms of this disease among troops. See also Dr Boileau's interesting essay in the same publication vol. viii.

thrice. Dysentery is common; tænia not infrequent; ophthalmia common, from dust and glare. Boils or anthrax are frequent; rheumatism is not uncommon, and phthisis is said to be frequent (from dust?). The death rate is said to be 21·3 per 1000 in the towns, and 28·7 in the country districts; while nearly 57½ per cent. of this is in children under five years,[*] the great causes of infantile mortality being registered as teething and convulsions.

### *Health of the Troops.*

The health of the troops is worse than at Gibraltar, but it has singularly fluctuated (even without great epidemics), more so probably than at any station in the same latitude. The mortality has varied as much as threefold without cholera.

| YEARS. | Loss of strength per 1000 per annum. | | | Loss of Service per 1000 per annum. | | |
|---|---|---|---|---|---|---|
| | Total Deaths. | Deaths from Disease. | Invaliding. | Admissions. | Mean daily Sick. | Days in Hospital to each Sick Man. |
| 1837–46, . . . . . . | 15·3 | ... | ... | 1120 | 43·79 | ... |
| 1861–70 (10 years), . | 13·49 | ... | 22·2 | 798·6 | 43·31 | 19·81 |
| 1865–74 (10 years), . | 14·24 | ... | 33·73 | 828·4 | 41·66 | 18·35 |
| 1875, . . . . . . . | 10·43 | ... | 24·92 | 906·1 | 42·21 | 17·34 |
| Highest (1865, cholera), | 26·44 | 24·63 | ... | ... | ... | ... |
| Lowest 1864, . . . | 6·53 | 4·58 | ... | ... | ... | ... |

The mortality in 1864 was as low as it has ever been; but it has in former years been as low as 5·6 from disease alone. It is curious how alternations of health and sickness occur chiefly from the variations in the fevers of different kinds, especially enteric (typhoid) and the remittent or so-called Malta fever, which has a long course, a great tendency to rheumatic sequel, and little mortality.

In 1867 there was a terrible outbreak of continued fever, chiefly among the troops quartered in the notoriously unhealthy barracks of Lower St Elmo and Fort Ricasoli. The admissions rose to 228, and the deaths actually amounted to no less than 7·93 per 1000 of strength. Out of 100 deaths no less than 32·2, or nearly one-third, were from "continued fever," *i.e.*, enteric fever in great measure.

In former years phthisis was the cause of 39 per cent. of the deaths, or nearly the same as at Gibraltar. Latterly there have been fewer deaths at Malta, but a considerable number of tubercular cases are sent home. The disease is probably detected earlier, and the men do not die as formerly at the station. Still this does not account for the whole diminution, and there has been clearly a lessening of phthisis. There was formerly a large amount of stomach and bowel disease, and dysentery was forty times as frequent as in England.[†] It is certainly a very remarkable circumstance, that both at Gibraltar and Malta there should have been this extraordinary liability to affections of the alimentary canal. At Malta, as at Gibraltar, it may have been chiefly owing to impure water and to food (Report of 1853, p. 118).

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[*] Report of Barrack Commissioners, p. 87. The Commissioners justly remark that these figures are so striking as to demand further inquiry. Probably they are quite untrustworthy; yet both at Gibraltar and Malta, it would be of the greatest importance, not merely for the health of the troops in peace, but for the security of the fortress in war, to know everything about the social life and the diseases of the native population.

[†] In England, in 1837–46, every 1120 men gave one case of dysentery; in Malta, in the same years, every twenty-eight men gave one case of dysentery. The mortality of the disease was, however, nearly the same (see pages 21 and 118 of the Report of 1853).

Of late years stomach and bowel affections have been less frequent, but are still more common than at home; in 1861, the 89,000 men on home service gave only 67 cases of acute dysentery, and no deaths, while the 6000 men at Malta had 34 cases and 2 deaths. In 1864 there were 3 deaths from acute dysentery among 5654 men, while in the home station there was only 1 death among 73,252 men. If it had been equally fatal at home, there would have been nearly 39 deaths.

A continued fever (which was probably in great measure typhoid) has prevailed more or less for the last forty years at Malta, and doubtless also before that time. It has been quite as prevalent and fatal of late years as formerly; in 1851 there were 1413 admissions out of a garrison of 5310 men, or at the rate of one man in every four; and the deaths from fever were 44 out of 96 total deaths, or 45·83 of the total mortality. In 1863 there were 844 admissions and 21 deaths out of a garrison of 5494 men. This is more than in any town or village in England. In 1864 there were 1057 cases and 6 deaths out of a garrison of 5654 men. In 1865 there were 1162 admissions and 13 deaths out of 5323 men; in 1866, 1031 admissions and 19 deaths out of 5202 men; and in 1875, 634 admissions and 11 deaths out of 4,506 men.

In the Statistical Report for 1853, it is observed that the number of cases of liver disease at Malta are remarkably high; and the writers, while believing there must be "something in the climate of Malta peculiarly favourable to the production of hepatic affections," were unable to find, on bringing the cases into relation with the temperature, any connection. The cause of this may be something very different, and it is very desirable that the food should be looked to. There is a suspicion at Netley (which requires a few years more experience to test it), that the cases of echinococcus of the liver are more frequent in men from the Mediterranean stations than others (Dr Maclean). The case of Iceland should lead us to look into this point.

The history of admission for venereal disease is important; in 1837–1846, inclusive, the admissions were only 99 per 1000, or two-thirds less than at home; in 1859, when the next report appeared, they were 149 per 1000; and in 1860 they were 147·9 per 1000. In the early period there were police regulations, which were suspended in the two latter years. In June 1861 the police regulations were re-enforced, and the admissions for the year sank to 102. The 4th battalion of the Rifle Brigade showed the following remarkable result:—In the first half of 1861 there were 57 admissions; in the last half only 17. In 1862 the total number of cases of "enthetic disease" in the whole garrison were only 49·5; in 1863, 44·1; and in 1864, 53·2 per 1000. They were increased in that year by the women who came from Ionia with the troops. In 1865 they were 44; in 1866, 59·6 per 1000. In 1870 and 1871, the admissions were very few; in the latter year, which was the worst, the admissions of primary syphilis were only 8·3 per 1000 of strength. If the home return is looked at, it will be seen what an effect has been produced at Malta by good regulations, although the number of cases fluctuates from causes traceable to special influences; the reduction is almost entirely of syphilis, not of gonorrhœa. The large number of admissions from phlegmon and ulcers is as striking in Malta as at Gibraltar and at home; and here as there, these are probably mere conventional terms. Such, then, in brief, seem to be the chief medical points of importance at Malta, viz., a liability to phthisis, less marked of late years; a great amount of fever, from bad sanitary conditions in great part; a liability to stomach and intestinal affections, which, though less obvious, is still great, and a singular tendency to a liver affection, which may be parasitic. The chief improvements advised by the Barrack Commissioners refer to a larger water supply, a better distribution, improved drainage, and efficient ventilation.

In time of war, the dangers at Malta would be the same as at Gibraltar; the aqueducts might be cut by a besieging force, and the water supply restricted to the tanks.[*] Although these are supposed to hold a large quantity, they are not kept full, and could not, perhaps, be rapidly filled. The garrison might be driven to distil the sea water. A still more serious danger would be the overcrowding of a war garrison. Doubtless, in case of a war, the garrison would only be concentrated in the lines when the siege commenced, but the crowding during a siege of three or six months might be very disastrous. This danger should be provided for beforehand by a clear recognition of what accommodation would be granted for war, and how it is to be obtained without violating either the conditions of health or of defence.

*On the Influence of Age on Mortality in Gibraltar and Malta.*

| | Deaths per 1000 of Strength at each Period. | | | | | |
|---|---|---|---|---|---|---|
| | Under 20. | 20–24. | 25–29. | 30–34. | 35–39. | 40 and over. |
| 1865–74 (ten years), | 3·04 | 6·28 | 14·28 | 14·38 | 22·22 | 31·58 |
| 1875, | 1·97 | 6·51 | 6·61 | 11·80 | 11·56 | 16·74 |

## SECTION II.

## WEST INDIES.

The history of sanitary science affords many striking instances of the removal of disease to an extent almost incredible, but no instance is more wonderful than that of the West Indies. Formerly, service in the West Indies was looked on as almost certain death. It is not fifty years since the usual time for the disappearance of a regiment 1000 strong was five years. Occasionally in a single year a regiment would lose 300 men, and there occurred from time to time epochs of such fatality that it was a common opinion that some wonderful morbid power, returning in cycles of years—some wave of poison—swept over the devoted islands, as sudden, as unlooked-for, and as destructive, as the hurricanes which so sorely plague the

> "Golden isles set in the silver sea."

What gave countenance to this hypothesis was, that sometimes for months, or even for a year together, there would be a period of health so great that a regiment would hardly lose a man. But another fact less noticed was not so consistent with the favourite view. In the very worst years there were some stations where the sickness was trifling; while, more wonderful still, in the worst stations, and in the worst years, there were instances of regiments remaining comparatively healthy, while their neighbours were literally decimated. And there occurred also instances of the soldiers dying by scores, while the health of the civil inhabitants in the immediate vicinity remained as usual.

If anything more were wanted to show the notion of an epidemic cycle to be a mere hypothesis, the recent medical history of the West Indies would prove it. At present this dreaded service has almost lost its terrors. There still occur local attacks of yellow fever, which may cause a great mortality; but for these local causes can be found; and otherwise the stations in the West Indies can now show a degree of salubrity almost equalling, in some cases surpassing, that of the home service.

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[*] Dr Notter has lately (1872) analysed fourteen of the tank waters of the different forts, and finds the condition of the water to be satisfactory.

The causes of the production, and the reasons of the cessation, of this great mortality are found to be most simple. It is precisely the same lesson which we should grow weary of learning if it were not so vital to us. The simplest conditions were the destructive agents in the West Indies. The years of the cycles of disease were the years of overcrowding, when military exigencies demanded that large garrisons should hold the islands. The sanitary conditions at all times were, without exception, infamous.

There was a great mortality from scorbutic dysentery, which was almost entirely owing to diet.* Up to within a comparatively late date, the troops were fed on salt meat three, and sometimes five, days a week, and the supply of fresh vegetables was scanty. It required all the influence of Lord Howick, the then Secretary at War, to cause fresh meat to be issued, though it had been pointed out by successive races of medical officers that fresh meat was not only more wholesome, but was actually cheaper. The result of an improvement in the diet was marvellous; the scorbutic dysentery at once lessened, and the same amount of mortality from this cause is now never seen. Another cause of dysentery was to be found in the water, which was impure from being drawn from calcareous strata, or was turbid and loaded with sediment. The substitution of rain water has sufficed in some stations to remove the last traces of dysentery.

If the food and water were bad, the air was not less so. Sir Alexander Tulloch has given a picture of a single barrack at Tobago, said to be the "best in the whole Windward and Leeward Command,"† the figures of which tell their own tale.

Barrack at Tobago in 1826.—Superficial space per man, 22½ feet; breadth, 23 inches; cubic space, 250 feet.

The men slept in hammocks, touching each other. In these barracks, crowded as no barracks were even in the coldest climates, there was not a single ventilating opening except the doors and windows; the air was fœtid in the highest degree. With this condition of atmosphere, it is impossible not to bring into connection the extraordinary amount of phthisis which prevailed in the soft and equable climate of the West Indies. There was more phthisis than in England, and far more than in Canada. The first great improvement was made in 1827, when iron bedsteads being introduced, each 3 feet 3 inches wide, greater space was obliged to be given to each man.

Every arrangement for removal of sewage was barbarous, and in every barrack sewage accumulated round the buildings, and was exposed to heat and air. When yellow fever attacked a regiment, every stool and evacuation was thrown into the cesspools common to all the regiment; and in this way the disease was propagated with great rapidity, and was localised in a most singular manner, so that a few hundred yards from a barrack, where men were dying by scores, there would be no case of fever. In spite of this, it was many years before the plan of at once evacuating a barrack where yellow fever prevailed was adopted.

The barracks themselves were usually very badly constructed, and when in some cases the architects had raised the barracks on arches from the ground, in order to insure perflation of air below the buildings, the arches were blocked up or converted into store-rooms; and the barracks, with spaces thus filled with stagnant air beneath them, were more unhealthy than if they had been planted on the ground.

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* This is pointed out in the Statistical Report (1838) on the West Indies, by Tulloch and Balfour; and it is believed that the improvement in the diet was in a great measure owing to these gentlemen.

† Report, 1838.

The localities for barracks were often chosen without consideration, or for military reasons,* into which no consideration of health entered. Almost all were on the plains, near the mercantile towns, where the soil was most malarious, and the climate hottest and most enervating. Malarious fevers were, therefore, common.

To all these causes of diseases were added the errors of the men themselves. For the officers there existed, in the old slave times, the greatest temptation. A reckless and dangerous hospitality reigned everywere; the houses of the rich planters were open to all. A man was deemed churlish who did not welcome every comer with a full wine, or more often a brandy, cup.

In a climate where healthy physical exertion was deemed impossible, or was at any rate distasteful, it was held to be indispensable to eat largely to maintain the strength. To take two breakfasts, each a substantial meal, was the usual custom; a heavy late dinner, frequently followed by a supper, succeeded; and to spur the reluctant appetite, glasses of bitters and spirits were taken before meals.

The private soldiers obtained without difficulty abundance of cheap rum, which was often poisoned with lead. Drunkenness was almost universal, and the deaths from delirium tremens were frequent and awfully sudden. The salt meat they were obliged to eat caused a raging thirst, which the rum bottle in reality only aggravated.

To us these numerous causes seem sufficient to account for everything, but in former days an easier explanation was given. It was held to be the climate; and the climate, as in other parts of the world besides the West Indies, became the convenient excuse for pleasurable follies and agreeable vices. In order to do away with the effects of this dreaded climate, some mysterious power of acclimatisation was invoked. The European system required time to get accustomed, it was thought, to these climatic influences, and in order to quicken the process various measures were proposed. At one time it was the custom to bleed the men on the voyage, so that their European blood might be removed, and the fresh blood which was made might be of the kind most germane to the West Indies. At other times an attack of fever (often brought on by reckless drinking and exposure) was considered the grand preservative, and the seasoning fever was looked for with anxiety. The first statistical report of the army swept away all these fancies, and showed conclusively that instead of prolonged residence producing acclimatisation and lessening disease, disease and mortality increased regularly with every year of residence.

The progress of years has given us a different key to all these results. It is now fully recognised that in the West Indies, as elsewhere, the same customs will insure the same results. Apart from malaria, we hold our health and life almost at will. The amount of sickness has immensely decreased; occasionally in some stations which used to be very fatal (as at Trinidad) there has not been a single death in a year among 200 men. Among the measures which have wrought such marvels in the West Indies have been—

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* The history of the old St James's Barracks in Trinidad is too remarkable to be passed over. It was determined to build a strong fort—a second Gibraltar—on the lower spurs of the hills overlooking the plain where the barracks now stand. When the works had been carried on for some time, it was discovered that they could not hold the troops. The barracks were then ordered to be placed on the plain, under cover of the guns of the fort. Before the fort was quite finished, it was found to be so unhealthy that neither white or black men could live there, and it was abandoned. The barrack, it is said, was not then commenced; yet, though the reason for placing it in that spot had gone, it was still built there, on a piece of ground near two marshes (Cocorite and the Great Western Marsh), below the general level of the plain, and exposed to the winds from the gullies of the neighbouring hills. Yet this bad position, so fruitful of disease, was in reality less injurious than the bad local sanitary arrangements of the old St James's Barrack itself.

1. A better supply of food; good fresh meat is now issued, and vegetables, of which there is an abundance everywhere.

2. Better water.

3. More room in barracks, though the amount of cubic space is still small.

4. Removal of some of the stations from the plains to the hills; a measure which has done great good, but which can explain only a portion of the improvement. The proper height to locate troops is by most army surgeons considered to be at some point above 2500 feet.

5. Better sewage arrangements, and more attention generally to sanitary conservancy.

6. A more regular and temperate life, both in eating and drinking, on the part both of officers and men.

7. The occupancy of the unhealthy places, when retained as stations, by black troops.

8. A better dress. It is only, however, within the last few years that a more suitable dress has, at the instance of the late Director-General, Sir J. B. Gibson, been provided for the West Indian Islands.

The army stations in the West Indies are, Jamaica, Barbadoes, Trinidad, St Vincent; the last three being included in the term "Windward and Leeward Command." British Guiana, on the mainland, is part of this command. There are small parties of artillery and some black troops in Honduras and the Bahamas.

The period of service is now three or four years; formerly it was eleven or twelve, but this was altered after the first statistical report. Usually the Mediterranean regiments pass on to the West Indies, and subsequently to Canada. The total number of men serving in the West Indies is now very small.

The proper time for arriving in the West Indies is in the beginning of the cold season, viz., about the beginning of December, when the hurricanes and autumnal rains are usually over.

## JAMAICA.

Present strength of white garrison, 300 to 400; black troops, 700 to 800. Population of Island at last census, 506,514. A range of lofty hills (Blue Mountains) divides Jamaica into two parts, connected by a few passes. The troops were formerly stationed chiefly in the south plains, at Kingston (30,000 inhabitants), Port-Royal, Spanish Town, Up-Park Camp, Fort-Augusta, &c. After the Maroon war in 1795 some troops were stationed at Maroon Town (2000 feet above the sea) on the north side, and at Montego Bay. Subsequently Stoney Hill (1380 feet above the sea), at the mouth of one of the passes, was occupied.

Since 1842 some, and now nearly all the troops, are at Newcastle, in the hills, 4000 feet above the sea, with detachments at Kingston and Port-Royal. The other stations are now disused for white troops. The sanitary condition at Newcastle was formerly not good; the sewage arrangements were very imperfect; it is now somewhat improved.

*Climate.*—The climate is very different at the different stations. At Kingston (sea-level)—temperature, mean of year = 78°·0; hottest month, July, mean = 81°·71; coldest month, January, mean = 75°·65; mean yearly fluctuation = 6°·06. Undulations trifling. The climate is limited and equable. At Newcastle the mean annual temperature is about 66°; hottest month, August = 67°·75; coldest month, February = 61°. The diurnal range is considerable, but the annual fluctuation is trifling (about 6°). The mean of the year is therefore much lower than on the plains; the amplitude of the yearly fluctuation about the same; the diurnal change greater.

*Humidity.*—This is considerable in the plains—often from 80 to 90 per cent. of saturation = 7 to 9 grains of vapour in a cubic foot. At Newcastle the mean yearly dew-point is about 60°; the amount of vapour in a cubic foot of air is 5·77; the mean yearly relative humidity is 68 per cent. of saturation.

*Rain.*—Amount on the plains = 50 to 60 inches, in spring and autumn, viz., April and May, and October and November. Showers in July and August.

*Winds.*—Tolerably regular land winds at night, and sea breezes in the hot and dry months during the heat of the day. The central chain of mountains turns the north-east trade wind, so that it reaches the south side diverted from its course; from December to February the wind is often from the north, and brings rain and fogs ("wet northers"). The south-east wind in April and May is very moist. The hurricane months are from the end of July to the beginning of November. The climate in the plains is therefore hot, equable, and humid.

### *Health of the Black Civil Population.*

Of the specific diseases, smallpox and the other exanthemata are common. Spotted typhus is said to be unknown; typhoid is said to be uncommon, but is probably more common than is supposed. Influenza has prevailed at times, and also the so-called dandy or polka (Dengue). Cholera has prevailed severely. Malarious fever is common over the whole of the south plains. Yellow fever is common, though less frequent and severe among the blacks than the whites. Dysentery is common, though it has always been less frequent than among the troops. Organic heart disease is frequent. Liver diseases are uncommon. Spleen disease, in the form of leucocythæmia, is common among the blacks (Smarda). Gout is said to be frequent, and scrofula and rickets to be infrequent. Syphilis is not common, but gonorrhœa is. Cancroid of the skin and elephantiasis of the Arabs (Pachydermia) are common. Leprosy is also seen.

### *Health of the Troops.*

In the years 1790–93 the annual mortality of the white troops varied in the different stations from 111 (Montego Bay) to 15·7 per 1000 of strength at Stoney Hill (1380 feet above sea-level). In the years 1794–97 the mortality was much greater; the most unhealthy regiment in the plains lost 333; the most healthy, 45·4 per 1000 of strength; at the hill station of Maroon Town (2000 feet), the mortality was, however, only 15·6 per 1000. In the years 1817–36 the mean mortality was 121·3; the mean of the four healthiest years gave 67, and of the four unhealthiest years 259 per 1000. The causes of death in these twenty years were—

| | | |
|---|---|---|
| Fevers, . . . . | 101·9 | per 1000 of strength. |
| Lung diseases, . . | 7·5 | " |
| Bowel complaints, . . | 5·1 | " |
| Brain disease, . . . | 2·6 | " |
| Liver diseases, . . | 1 | " |
| Other complaints, . . | 3·2 | " |
| | 121·3 | " |

The admissions in these years were 1812 per 1000 of strength. In 1837–55 the following were the mean results:—Mortality per 1000 of strength—white troops, 60·8; black troops, 38·2. Admissions per 1000,—white troops, 1371; black troops, 784. So that the mortality had declined one-half.

In 1864 the mortality was much below the home standard. In 1867 it ran up nearly to the old amount, from the prevalence of yellow fever, which in that year prevailed again in Newcastle, and caused a greater loss than it had done in 1860. At present the statistics of the white troops are—

| Years. | Loss of Strength per 1000 per Annum. | | | Loss of Service per 1000 per Annum. | | |
|---|---|---|---|---|---|---|
| | Total Deaths. | Deaths from Disease. | Invalids. | Admissions. | Mean Daily Sick. | Days in Hospital in each Sick Man. |
| 1861–70 (10 years), . | 20·36 | ... | 27·6 | 930·8 | 40·68 | 16·10 |
| 1871, . . . . . . . | 13·51 | 13·51 | 30·4 | ... | 32·48 | 15·17 |
| Highest in 1867, . . | 71·09 | 69·80 | 45·91 | 1192·9 | 78·95 | 21·95 |
| Lowest in 1864, . . | 7·35 | 5·88 | ... | ... | ... | ... |
| In 1875 the death rate was, . . . . . | 12·99 | ... | ... | ... | ... | ... |

An increase in admissions and mortality occurred in 1865 and 1866, owing to the exposure of the troops in the time of the negro disturbances, and their subsequent partial location on the plains.

Before this period Jamaica contrasted favourably even with home service, and particularly so with India.

A decrease of admissions in 1859–64 was chiefly owing to the comparatively small number of cases of paroxysmal disease; a decline consequent on the removal of most of the troops from the plains (in 1859 Newcastle gave 29·1 admissions, and Port-Royal, on the plain, 443·5 per 1000 of strength, from malarious disease). In 1863 some white troops were sent to Up-Park Camp, and furnished a large number of malarious cases (547·6 admissions per 1000 of strength), while at Newcastle they were only 48 per 1000. The decrease in the mortality in the years 1859–64 was owing to lessened fever and dysentery. Among the black troops there is now greater sickness and mortality than among the whites; the mortality in 1837–55 was 38·2 per 1000; in 1859–65 it was 27·33; in 1866, 23·03 per 1000; in 1875 it was only 14·67. There is among these troops a large mortality from paroxysmal fevers, phthisis, and diseases of the alimentary canal; and it is evident that their condition requires a close examination.

The mortality of the white troops shows a marked increase with age.

The following seem to be the most important points connected with the white troops which require notice.

It is impossible to avoid paroxysmal fevers without placing all the troops in the hills, and it is very desirable Newcastle should be made the only station for white troops.

The possibility of yellow fever occurring at an elevation of 4000 feet was shown by the appearance of yellow fever at Newcastle in 1860 and 1867. In 1860 occurred the remarkable instances of contagion on board the ships "Icarus" and "Imaum" described by Dr Bryson. Whether yellow fever was imported into Newcastle or not was a subject of discussion; it certainly appears probable that it was carried there; but the important point for us is that mere elevation is not a perfect security. There were, however, only a small number of cases. In 1867, when yellow fever again appeared at Newcastle, it was imported, apparently, from Kingston and Up-Park Camp.

In the returns for a number of years, cases were returned as "continued fever;" it had never been clearly made out whether or not these were cases of typhoid fever until 1873-4, when a sharp epidemic occurred at Newcastle.

Formerly there was a large number of cases of phthisis; phthisis is now uncommon; in 1817-36 lung diseases (almost entirely phthisis) caused 7·5 deaths per 1000 of strength, or more than in England. In 1859-66 the ratio was only 1·42 per 1000 of strength; and in 1861, out of 636 men there was not a single death, though four men were sent home with consumption. In 1865 there was no death; eight men were sent home.

At Newcastle there occurred for some years an excess of affections of the alimentary canal, chiefly indigestion; at present these have lessened, but it would be important to make out the cause. In 1860 there was not a single admission from dysentery at any station.

In the worst times in Jamaica it was always remarked that there was rather a singular exemption from acute liver disease; very few cases appear in the returns under hepatitis; whether this is a matter of diagnosis, or whether there was really an immunity compared with India or the Mauritius, is a question of great interest which cannot now be solved. At present, liver disease unconnected with drinking is uncommon.

There is still too much drinking, and the medical officers have strongly advised the issue of beer instead of the daily dram.

Venereal diseases have never prevailed much in Jamaica; they have caused, on an average, from 70 to 90 admissions per 1000 of strength. In 1862 there were only 47 admissions per 1000 of strength. On an average in 1859-65, enthetic diseases gave 118 admissions per 1000. This is owing to the connection usually formed between the black women and the soldiers, and to a lessened amount of promiscuous intercourse.

The history of the years 1865-67 shows that the greatest care and the most judicious arrangement of the men is necessary to guard against a recurrence of the old evils.

The black troops give a mortality of 24·6 per 1000 (mean of 10 years, 1861-70), especially from phthisis.

### TRINIDAD.

Strength of garrison, 200 men. Civil population (in 1871) about 110,000.

*Geology.*—Tertiary formation of Miocene age; central range of hills is an indurated formation of Cretaceous age; the northern littoral range consists of micaceous slates, sandstones, limestones, and shales. The highest hill is 3012 feet; the central hill (Tamana) is 1025; $\frac{1}{11}$th of the island is swampy.

*Climate.*—Temperature of the plains: Mean of year about 79°·3; coldest month, January = 78°; hottest month, May = 81°·5; next hottest, October = 80°·4. Mean annual fluctuation, 3°·5. The climate is therefore very equable and limited. There are, however, cold winds from the hills blowing over small areas.

*Hygrometry.*—Mean dew-point, 75°·1; mean relative humidity = 81 per cent. of saturation; mean weight of vapour in a cubic foot = 9·4 grains; most humid month is May, as far as the amount of vapour is concerned. Month with greatest relative humidity, August.

*Winds* from east to north-east and south-east. West winds rare, and oppressive.

*Rain on the Plains* about 60 or 70 inches. Greatest rainfall in one day, 4·67 inches. Dry season, December to May. June and July showery. Heavy rain in August, September, and October.

*Sanitary Condition.*—St James' Barrack is on a depression on an alluvial soil three miles from Port of Spain, the capital; it is one mile from the Cocorite, and three from the Great Eastern Swamp; the drainage, for many years most defective, is now improved, as the main sewer is carried to the sea. On many occasions yellow fever has prevailed in this barrack, and nowhere else in the island; the last occasion was in 1858–59, and then it was proposed by Dr Jameson (the principal medical officer) to erect barracks on a spot 2200 feet above sea-level.

The capital, the Port of Spain (22,000 inhabitants), is built at the principal outfall of the island; it is on a low and unhealthy plain. Formerly, it was so unhealthy as to be scarcely habitable, but after being well drained and paved by Sir Ralph Woodford, it has become much healthier. This was the result of great sanitary efforts in a very unpromising locality, and should be a lesson for all climates.

There is still, however, much malarious disease, dysentery, and at times yellow fever; but this last disease has occasionally been very severe at St James' Barracks, without a single case being seen in Port of Spain. The ascent of the malaria from the barrack plain is certainly more than 500, and probably as much as 1000 feet.

*Diseases of Troops.*—The state of health has been and is very similar to that of Jamaica, with, however, a larger percentage in former years both of phthisis and diseases of the stomach and bowels, chiefly dysentery.

In the years 1817–36, the average mortality of the white troops was 106·3 per 1000 of strength, and of these deaths there were—

| | |
|---|---|
| From fevers, | 61·6 |
| Lung diseases, | 11·5 |
| Diseases of stomach and bowels, | 17·9 |
| Dropsies (probably partly malarious, partly renal), | 7·7 |
| Brain diseases (especially from intemperance), | 4·7 |
| Liver diseases, | 1·1 |
| All other diseases, | 1·8 |
| | 106·3 |

As in Jamaica, the statistics of the white troops of late years tell a very different story.

In 1859 there was an outbreak of yellow fever, and the deaths from disease rose to 84·27 per 1000. In the next seven years (ending 1866) the average number was 7·48 deaths from disease per 1000. In two years (1860 and 1865) there were no deaths.

Even in 1859, when the mortality was so large, there were only 10 deaths from yellow fever among 190 men, while there were no less than 4 deaths from delirium tremens.

Among the diseases in the returns, the largest item is malarious fever; there are also cases of "continued fever," as in Jamaica; and this term, in fact, has never been absent from the reports. Is this typhoid fever? In all probability it is, as unequivocal typhoid fever does occur in Trinidad. (See Dr Stone's paper in the *Medical Times and Gazette*, Feb. 1860.) A considerable number of cases of dyspepsia are admitted; in 1860 there were 16 cases out of 221 men, or 72 per 1000 of strength. In 1862 there were 103 per 1000 admissions, from "digestive" diseases. Venereal diseases have always been low; in 1860, 1861, 1862, and 1864, there were only 49·6, 44·4, 20·6, and 63·8 admissions per 1000 of strength. Dysentery is now infrequent. In 1860, out of 221 men, and in 1861, out of 225 men, there was not a single case. In 1864, out of 235 men, there was only 1 case. In 1865 there were no admissions from phthisis. Phthisis is much less common, yet in some years there is still too much of it.

It is evident that if Dr Jameson's suggestion is acted upon, and the troops are removed to the hills, malarious fever will disappear, and yellow fever can be prevented. In such a case, if the men will abstain from drinking, this island, which formerly killed rather more than 1 man in every 10 yearly, will be one of the healthiest spots in the world.

The black troops are now less healthy than the white, having in 1859–65 an annual mortality of nearly 20 per 1000, of which 18 were from disease. Their condition requires looking into. Of late years a very small number of black troops have been stationed at Trinidad.

The invaliding from Trinidad is combined in the Army Reports with that of the other islands of the Windward and Leeward Commands.

### BARBADOES.

Strength of garrison, 500 to 600 men. Civil population (in 1871), 162,042.

*Geology.*—Limestone (coralline); sandstone (tertiary); beds of bituminous matter and coal (tertiary), clay in parts (especially in the hilly district called "Scotland").

An open country, well-cultivated, no marshes except a small one at Græme Hall, one mile to the east of St Ann's Barracks.

The country is divided into two parts: a mountainous district termed "Scotland," and a lower country consisting of a series of five gigantic terraces, rising with some regularity one above the other. The highest hill is 1100 feet.

*Climate of the Plain.*—Temperature: Mean of year, 80°; hottest month (October), 83°; coldest month (January), 78°; mean yearly fluctuation, 5°. Climate equable and limited.

*Wind.*—N.E., trade, strongest in February to May; weak in September to November inclusive; hurricane month, August.

*Rain.*—About 56 to 58 inches, on an average, but varying a good deal in the autumn chiefly, though there is rain in all months, but much less. The dry season is from December to May.

*Water.*—Formerly supplied from wells; it was highly calcareous. At present good water is supplied by a water company. Rain water is also collected in tanks.

*Sanitary Condition.*—St Ann's Barracks are placed above one and a half mile from Bridgetown, on the sea; the locality and the construction of the barracks have been much complained of, and a position in the hills advised.* Arrangements for sewering and the water supply were both formerly bad; considerable improvements have been made, and, since 1862, 30,000 gallons are supplied daily to St Ann's Barracks. It is a limestone water, containing carbonate of lime, but no sulphate of lime, and is remarkably free from organic matter. The total solids are 18·72 grains per gallon. The troops are still too much crowded in barracks, the allowance being under 600 cubic feet. Since 1872 new latrines (Jennings' pattern) have been provided and the old ones closed.

Formerly vegetables were very deficient in Barbadoes, and even now there is some difficulty in procuring them. They are often imported from other

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* For an extremely good and concise account of Barbadoes, see Dr Jameson's Report in the Army Medical Report for 1861, p. 281.

*among Civil Population.*—Yellow fever has appeared frequently, although the island is not marshy. It is not so frequent as formerly; it used to be expected every four years.

Barbadoes and Trinidad contrast greatly in the freedom from marshes of the one, and the existence of marshes and malarious diseases in the other; yet Barbadoes has had as much yellow fever as Trinidad.

Dysentery was common formerly, partly from bad water; influenza has been epidemic several times. Barbadoes leg, or Elephantiasis of the Arabs, is frequently seen. Leprosy, or Elephantiasis Græcorum, is also not very uncommon. Variola and Pertussis have from time to time been very bad.

Hillary, in 1766, described a "slow nervous fever," under which term our typhoid fever appears to have been indicated by most writers of that period. His description is not quite clear, but resembles typhoid fever more than any other. He also speaks of "diarrhœa febrilis." Can this have been typhoid?

Dracunculus was formerly very frequent, and Hillary attributes it to the drinking water, and states that there were some ponds, the water of which was known to "generate the worm if washed in or drank."

Yaws used to be common.

Colica pictonum was formerly frequent.

*Diseases of Troops.*—Yellow fever has several times been very fatal.

Scorbutic dysentery, arising from the wretched food, was formerly very frequent, and appears from Sir Andrew Halliday's work to have been very bad even in his time (1823 to 1832).

From 1817 to 1836 (20 years)—

| | | | |
|---|---|---|---|
| Average Mortality (white troops), | 58·5 | per 1000 of strength. | |
| Greatest " . | 204 | " " | (in 1817). |
| Least " . | 18 | " " | (in 1823). |

In 1817 there were 1654 men on the island, and yellow fever broke out. In 1823 there were only 791.

Of late years, as in all the other islands, the sickness and mortality has been comparatively trifling.

In 1859–65 the total deaths were 6·98 per 1000, and in 1866 they fell to 3·28 per 1000, which is only ⅓d the mortality of home service. The highest mortality of late years was in 1862, viz., 16·77; the average number of admissions is about 1200.

In 1864 there was an outbreak of a mild fever, termed "remittent;" the nature is unknown; no case was fatal.

The increased mortality of 1862 was owing to yellow fever. It appeared first among the civil population in Bridgetown, and afterwards attacked the troops in the (stone) barracks. As it continued to spread, the men were moved out and placed under canvas, with the best effects. A remarkable feature of this epidemic was that the officers suffered in attacks six-fold more than the men, and had a mortality more than twenty-fold. The women also suffered three-fold more than the men. Formerly the case would have been reversed. In 1861 there were only two deaths out of 787 men, one from phthisis and one from apoplexy; and in 1864 there were also only two deaths (diarrhœa and phthisis) among 930 men.

Dysentery is now uncommon.

The great improvement to be made at Barbadoes is decidedly a complete change of barracks. The persistent recurrence of yellow fever in these old barracks, with their imperfect arrangements, shows them to be the main cause of the appearance of the disease. The saving in the cost of a single epidemic would amply repay the outlay.

As in the other islands, the black troops are now much more unhealthy than the white, and the sanitary condition of their barracks and their food evidently require looking into. Phthisis and chronic dysentery are the chief diseases causing mortality. The average of 1859–64 gave 1015 admissions and 20·46 deaths per 1000 of strength. In 1865 there were 22·64 deaths per 1000 of strength, or, excluding violent deaths, 20·49; of these phthisis caused 14·34, or no less than 70 per cent. of total deaths.

## St Lucia.

Strength of garrison = 100 men, now usually black troops. Civil population (in 1871), 36,610.

St Lucia is divided into two parts: Basseterre, the lowest and most cultivated part, is very swampy; Capisterre, hilly, with deep narrow ravines, full of vegetation. The climate is similar to that of the other islands, but is more rainy and humid.

*Diseases of the White Troops.*—From 1817–36; average strength, 241; average deaths, 30 = 122·8 per 1000 of strength. Of the 122·8 deaths, 63·1 were from fevers, 39·3 from bowel disease, and 12·5 from lung disease.

Pigeon Island (a few miles from St Lucia) was formerly so unhealthy that on one occasion 22 men out of 55 died of dysentery in one year, and of the whole 55 men not one escaped sickness. The cause is supposed to have been bad water. Now Pigeon Island is considered healthy.

Although the mortality was formerly so great, St Lucia has been very healthy for some years.

In 1859, mean strength of white troops, 96; admissions, 113, and there was not a single death, although, if the mortality had been at the rate of the twenty years ending 1836, 12 men would have died.

Better food, some improvement in barracks, and the use of rain instead of well water, have been the causes of this extraordinary change.

22 men were admitted with "continued fever," 18 with ophthalmia, and only 2 with venereal.

In 1860 there was no case of dysentery and only two of diarrhœa among 100 men in this island, where formerly there would have been not only many cases, but four deaths. One man died from phthisis, or at the rate of 10 per 1000.

In 1861, out of 94 men, there was one death from jaundice, or at the rate of 10·6 per thousand.

In 1862, there was 88 men on the island; one man was drowned; there was no death from disease. No case of jaundice was admitted.

In 1863 there was 55 men, and one death from accident; there were 64 admissions, of which 15 were accidents.

*Invaliding.*—In 1860–65 there was discharged from the Windward and Leeward Command 28·86 per 1000 of strength.

## British Guiana. (193,941 inhabitants.)

No white troops are at present stationed at Demerara.

This station in the West Indian Command is on the mainland, extending from the equator (nearly) to 10° N., 200 to 300 miles, and inland to an uncertain distance.

It is a flat alluvial soil of clay and sand, covered with vegetation.

The water of Georgetown is not good; it is drawn from a fresh-water lake and an Artesian well; the water from this well contains a good deal of iron.

Trade winds fom N.E. and E. for nine months. In July, August, and September, S.E. and S. and land-winds. This is the unhealthy season.

Two wet seasons, January and June; the last is the longest.

Temperature of summer, 86°; of winter, 82°. Rain about 100 inches.

Formerly there was an enormous mortality among the troops from yellow fever and scorbutic dysentery. The men used to have salt meat five times a week.

The climate is most highly malarious, but this does not cause much mortality.

Yellow fever has prevailed here several times. On one occasion (1861) the troops were moved out and encamped at some distance from Georgetown; they escaped (seven mild cases only), although they were on a swampy plain.

In 1817–36, the average deaths were 74 per 1000 of strength.

In 1859, out of a mean strength of 143, there were 156 admissions = 1091 per 1000 of strength; 2 deaths = 13·9 per 1000 of strength. One death from apoplexy, one from drowning. The deaths from disease were only 6·9 per 1000. Of the 156 admissions, no less than 81 were from malarious disease, or at the rate of 519 per 1000 of strength, or nearly one-half the total admissions.

In 1860, 1861, and 1862, the admissions from malarious disease continued high (673, 1380, and 1104 per 1000 of strength), the mortality was very small, being only 6·6 per 1000 in each year; in fact, the single death in 1860 and in 1861 was in one year from "acute hepatitis," and in the other from accident. In 1862, in spite of the immense malarious disease, there was no death.

Subsequently to 1861 it appears that scattered cases of follow fever occurred among the shipping, and in the town every year; in 1866 there was an outbreak among the white troops. In eight weeks 16 deaths occurred among 72 men, or 22 per cent.*

Some important lessons are drawn from the medical history of this station. It has been shown that even in a highly malarious country yellow fever may be evaded by change of ground, although the men are obliged to encamp on a swamp. Another remarkable point is the very small mortality attending the paroxysmal fevers. It would be very interesting to know the future history of such men, but it cannot be doubted that the lessened mortality since former years must be owing to better treatment.

The extent of malarious disease shows how desirable it would be to avoid sending white troops to Demerara.

In French Guiana, Dr Laure, besides malarious fevers, describes typhoid fever to have been for some short time after the arrival of French political prisoners after the *coup d'état* of 1851. It then disappeared.

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* A full inquiry was made into this outbreak; it was, as so frequently happens, localised, for the troops were suffering severely, while the health officer for the port (Dr Scott) states in his evidence (Report of the Commissioners appointed to Inquire into the Outbreak of Yellow Fever at Demerara in 1866, p. 35) that the cases in town were "very few" at the time. The barracks were badly circumstanced in various ways, particularly in having removal of sewage on a trench system, into which the latrines opened, and which trenches were intended to be kept clean by flushing; they were, however, in a very foul state, and were merely open cesspools; and the evidence of Surgeon-Major Hutton (Report p. 37) clearly points out that a thorough good system of dry removal is the proper plan for this colony. Whether this and the other unsanitary conditions gave its local development to the yellow fever, was a matter of doubt in the colony, but they are precisely the same conditions which have been so frequently seen in West Indian outbreaks,—a foul soil, and, in addition, open cesspools exposed to the intense heat of a tropical sun, and to the influence of a moist atmosphere and a moist soil. On this occasion the troops were not removed from the barracks until too late.

### BAHAMAS AND HONDURAS.

The black troops garrison both those places, and show a degree of mortality nearly the same as in the other stations, the amount of phthisis being very great. In 1862, at the Bahamas, there were no less than 4 deaths from phthisis out of a strength of 439, or at the rate of 9·1 per 1000 of strength; there were also 3 deaths from pneumonia and 1 from pleurisy. In the year 1859–66 the average deaths from tubercular diseases per 1000 men, were 11·04 yearly, and from other diseases of the lungs, 5·86; out of 100 deaths 60 were from diseases of the lungs. This is evidently a matter for careful inquiry.

At Honduras, among the black troops, the deaths from tubercular disease, in 1859–66, were 4·04 per 1007 of strength.

## SECTION III.

## BERMUDA.

Usual strength of garrison about 1108 to 1300 men. Civil population (in 1871), 15,309.

*Climate.*—Hot, equable, and rather limited.

*Temperature.*—Mean of year, 74°; hottest month (July), 83°·5; coldest month (February), 64°·5; amplitude of yearly fluctuation, 19°·0.

The sanitary condition was formerly very bad; there were no sewers, and no efficient dry method of removal. Now matters are much improved, and in 1875 the health of the troops was reported excellent. Rain water is used for drinking.

*Diseases of the Troops.*

| YEARS. | Loss of Strength per 1000 per annum. | | | Loss of Service per 1000 per annum. | | |
|---|---|---|---|---|---|---|
| | Total Deaths. | Deaths from Disease. | Invaliding. | Admission. | Mean Daily Sick. | Days in Hospital to each Sick Man. |
| 1817–36, . . . | 28·8 | ... | ... | 768 | ... | ... |
| 1837–46, . . . | 35·5 | ... | ... | 1080 | .. | ... |
| 1861–70 (10 years), | 26·02 | ... | 20·6 | 764·3 | 39·54 | 15 |
| 1867 (highest; yellow fever year), | 169·54 | 168·83 | ... | ... | ... | ... |
| 1860 (lowest), . . | 8·55 | 5·70 | ... | ... | ... | ... |
| 1865–74 (ten years), | 15·04 | ... | 21·92 | 716·5 | 35·39 | 18·27 |
| 1875, . . . . . | 11·05 | 8·95 | 19·93 | 601·4 | 33·03 | 20·07 |

This history of the West Indies may be applied to Bermuda, though, with the exception of yellow fever years, it never showed the great mortality of the West Indies. There is no great amount of paroxysmal fevers; in ten years (1837–46) there were only 29 admissions out of an aggregate strength of 11,224 men.

Yellow fever has prevailed seven times in this country—viz., in 1819, 1837 1843, 1847, 1853, 1856, and 1864.

The history of the yellow fever in 1864 is given in detail by Dr Barrow.* The total mortality was 14 officers, 173 men, 5 women, and 4 children. The deaths to strength were, among the officers, 18·9, and among the men, 14·9 per cent. The officers' mortality was owing to a large number of deaths among the medical officers.

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* Army Medical Report, vol. v. p. [illegible].

The town of St George's, in Bermuda, presents every local condition for the spread of yellow fever; the town is quite unsewered; badly supplied with water; badly built.

"Dandy fever," or break-bone (Dengue), has prevailed several times.

"Continued fevers" (no doubt in part typhoid) have always prevailed more or less at Bermuda. In the ten years (1837–46) they gave 1004 admissions out of 11,224 men, or 88 per 1000 of strength, being much greater than at home.

In 1859 there were only 11 cases of "continued fever" out of 1074 men; but in 1860, "continued fever" prevailed severely (209 cases in 1052 men). It was of a mild type, and caused little mortality. It was probably not typhoid, but I have learned nothing definite of its nature. It prevailed in September, October, and November. Was it mild, bilious, remittent, or "relapsing fever?" It is said that the drainage was defective at Hamilton.

In 1866 there was decided typhoid fever, and a considerable mortality. In 1875 there were 5 admissions recorded and 1 death in 1902 men.

Formerly tuberculous diseases caused a considerable mortality. In the years 1817–36, diseases of the lungs gave a mortality of no less than 8·7 per 1000 of strength. In 1837–46, the lung diseases gave a yearly mortality of 8·3 per 1000 of strength. Of late years the amount has decreased. The admissions and deaths respectively were 10·5 and 2·6 in the seven years 1859–65. In 1870 the deaths from phthisis were 1·57, and in 1871 no less than 5·19 per 1000 of strength; in 1875 they were 1·58.

Diarrhœa and dysentery were also formerly very common, but of late years there has been a great decrease. Diseases of the eyes are common.

There has always been much intemperance, and a large number of deaths from delirium tremens. This was the case even in 1866; there were no less than 5 deaths out of a total of 28.

Venereal diseases have averaged from 55 to 80 per 1000 of strength.

In considering the sanitary measures to be adopted at Bermuda, it would seem that drainage and ventilation are still most defective, and that means should be taken to check intemperance. If yellow fever occurs, the measures should be the same as in the West Indies.

## SECTION IV.

## AMERICAN STATIONS.

### SUB-SECTION I.—CANADA.*

The usual garrison used to be from 3000 in profound peace, to 10,000 or 12,000 in disturbed times. In 1871 the troops were withdrawn from Canada and concentrated at Halifax.

### LOWER CANADA.

*Chief Stations*—1. *Quebec* (59,699 *inhabitants*).

*Temperature.*—Mean of year, 41°; hottest month (July), 71°·3; coldest (January), 11°. Annual fluctuation, 60°·3.

The undulations of temperature are enormous. In the winter, sometimes, there is a range of 30, 40, and even more degrees in 24 hours, from the alternation of northerly and southerly winds. In one case the thermometer fell 70° in 12 hours. The mercury is sometimes frozen.

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* For an excellent account of the Canadian stations, see Sir W. Muir's Report in the Army Medical Reports for 1862, p. 375.

The mean temperature of the three summer months is 69°; winter months, 12°·8. The climate is "extreme" and variable.

*Rain.*—About 36 to 40 inches. The air is dry in the summer, and again in the depth of winter.

*Barracks.*—Built on lower Silurian rocks. No ague is known, though the lower town is damp.

Amount of cubic space small. Casemates in citadel very bad, damp, ill ventilated, ill lighted.

### 2. *Montreal* (107,225 *inhabitants*).

*Temperature.*—Mean of year, 44°·6; hottest month (July), 73°·1; coldest (January) 14°·5. Annual fluctuation, 58°·6. The undulations are very great, though not so great as at Quebec.

Mean of the three summer months, 70°·8; of the three winter months, 17°·2.

*Rain.*—36 to 44 inches.

*Barracks.*—Bad; very much overcrowded.

In Lower Canada are also many smaller stations.

## UPPER CANADA.

### *Chief Stations*—1. *Toronto* (70,000 *inhabitants*).

*Temperature.*—Mean of year, 44°·3; hottest month (July), 66°·8; coldest (February), 23°·1. Difference, 43·7. Great undulations.

*Rain.*—31·5 inches.

The town stands on ground originally marshy. The new barracks are built on limestone rocks of Silurian age. Average cubic space, only 350. Drainage bad.

Intermittent fevers among the civil population; not very prevalent among the troops.

### 2. *Kingston.*

*Temperature.*—Mean of year, 45°·8.

Malarious.

London, Hamilton, and several smaller stations—Fort George, Amherstberg, &c.—were also occupied at one time.

### *Diseases of the Civil Inhabitants.*

Formerly ague was prevalent in Upper Canada, especially in Kingston; it is now much less. At Montreal ague used to be seen; now is much less frequent. It prevails from May to October, and is worst in August.

If the isothere (mean summer temperature) of 65° be the northern limit of malaria, both Quebec and Montreal are within the limit; yet the winter is too severe, and the period of hot weather too short, to cause much development of malaria.

The climate is in both provinces very healthy, and has been so from the earliest records, though, when the country was first settled, there was much scurvy.

Typhoid is sometimes seen. Typhus has been often carried in emigrant ships, but has not spread, or at least has soon died out. Cholera has prevailed. Yellow fever dies out. Consumption is decidedly infrequent.

Acute pulmonary diseases used to be considered the prevalent complaints, but it is doubtful whether they are much more common than elsewhere.

### *Diseases of the Troops.*

Years 1817–36 (20 years).—Admissions per 1000 of strength = 1097; deaths 16·1 (without violent deaths).

Years 1837–46 (10 years).—Yearly admissions per 1000 of strength, 982; average daily sick per 1000 of strength, 39·1; mortality (violent deaths excluded), 13; mortality with violent deaths, 17·42.

The mortality was made up in part of—fever, 2·13; lung disease, 7·44; stomach and bowels disease, 1·11; brain disease, 1·28. Nearly two-thirds of the fevers are returned as "common continued," probably typhoid.

Venereal admissions, 117 per 1000.

Erysipelas was epidemic at Quebec, Montreal, and Toronto in 1841; at Montreal in 1842, from bad sanitary conditions.

The following table shows the mean of the later years :—

| YEARS. | Loss of Strength per 1000. | | | Loss of Service per 1000. | | |
|---|---|---|---|---|---|---|
| | By total Deaths. | By Deaths from Disease. | By Invaliding. | Admissions. | Mean Daily Sick. | Days in Hospital to each Sick Man. |
| 1861–70 (10 years), . . | 9·01 | ... | 15·9 | 646·9 | 30·36 | 17·14 |
| 1871, . . . . . . . | 9·55 | 5·87 | 17·6 | 679·8 | 33·15 | 17·8 |

### *Influence of Age on Mortality.*

| | Under 20. | 20-24. | 25-29. | 30-34. | 35-39. | 40 and over. |
|---|---|---|---|---|---|---|
| 1861–70 (10 years), | 3·47 | 6·01 | 9·80 | 11·13 | 17·66 | 20·23 |

These numbers show, what indeed is apparent in all the records, that Canada is a very healthy station.

The amount of phthisis has always been smaller than on home service, and regiments of the Guards proceeding from London to Canada have had on two occasions a marked diminution in phthisical disease.

In this respect, also, Canada contrasted formerly with the West Indies, but of late years the decline of phthisis in the West Indies has lessened the superiority of Canada.

The comparatively small amount of phthisis is remarkable, as the troops have at times been very much crowded in barracks. They have now the home allowance of space (600 cubic feet).

Of late years phthisis has declined considerably with improved barrack accommodation.

In the 20 years, 1817–36, the annual admissions were 6·5, and the deaths 4·22, per 1000 of strength.

In the years 1859–65 the admissions from the whole tubercular class were 8 3, and the deaths were 1·67, per 1000 of strength.* It is curious to observe that this diminution has been coincident with a similar change at home.†

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* Still the lung complaints are higher than they should be. Sir William Muir (Army Med. Report, vol. viii. p. 55), after detailing the measures taken by him to improve the Barrack accommodation, says, "I cannot help thinking that the large number of men treated and invalided for chest disease, during the five years I have been on this command, bears a close relationship to this impure state of barrack air."

† In contrasting the consumptive invalidity at Gibraltar, Bermuda, and Canada, the Reporters of 1839 (Army Med. Report) remark that the returns "afford another interesting proof how little the tendency to consumption is increased either by intensity of cold or sudden atmospherical vicissitudes." See also the remarks on Phthisis in India at a subsequent page.

The acute lung affections, pneumonia, and acute bronchitis, appear formerly to have been rather more prevalent in Canada than they are now.

The following table gives the mean and extremes for 8 years (1859-66):—

| | Per 1000 of Strength. | |
|---|---|---|
| | Admissions. | Deaths. |
| Pneumonia—Mean, | 12·24 | ·8576 |
| Highest, | 15·33 | 1·996 |
| Lowest, | 7·91 | ·411 |
| Acute bronchitis—Mean, | 42·67 | ·309 |
| Highest, | 49·79 | ·719 |
| Lowest, | 28·48 | ·092 |
| Average of the mean of both, | 27·45 | ·5833 |

If this table is compared with the similarly constructed table (at page 615), showing the prevalence of these diseases at home, it appears that both pneumonia and acute bronchitis are rather more fatal in Canada. Both together gave a mortality of ·856 per 1000 at home, and 1·166 per 1000 in Canada. The admissions from pneumonia are also higher, but those from acute bronchitis are one-third less than at home, showing that the common catarrhal affections are probably less frequent in Canada. On the whole, however, the influence of the severe climate and the exposure on guard in Canada produces less effect than might have been anticipated.

"Continued fevers" (probably enteric) almost yearly give some mortality; the mean being about ·6 per 1000 of strength. This is actually more than on home service, and depends probably on the difficulties connected with drainage. A good dry system is the only plan which can be depended on in Canada.

The great healthiness of Canada in part probably depends on the fact, that the extreme cold in winter lessens or prevents decomposition of animal matter and the giving off of effluvia; hence, in spite of bad drainage and deficient water, there is no very great amount of fever. In the hot summer, the life is an open-air one. Even in winter the dry cold permits a good deal of exercise to be taken.

The amount of drunkenness and delirium tremens in Canada used to be great. In 1863 no less than 9 out of 96 deaths, or nearly one-tenth, were caused by delirium tremens. Violent deaths also are usually large, drowning giving the largest proportion.

The sickness and mortality of Nova Scotia and Newfoundland are almost identical with Canada, and they are now included in the returns under the one head of "Dominion of Canada." Both stations have always been considered very healthy. There is some typhoid fever at Halifax, and at both places there was formerly much drinking, but that is now less. In British Columbia, where there is a small garrison of 100 to 150, the health is also extremely good.

## SECTION V.

## AFRICAN STATIONS.

### SUB-SECTION I.—ST HELENA.

Garrison, 350 to 700. In 1875 only 185. Civil population (in 1871), 6,241.

Until very lately this small island has been garrisoned by a local corps (St Helena Regiment). The system is now altered, and a West India Regiment now serves in the island for three or four years.

The island has always been healthy; seated in the trade-winds, there is a tolerably constant breeze from south-east. The average mortality in the years 1859–66 was 9·75, or without violent deaths, 7·85. In 1867 the mortality from disease was only 5·24. In 1875 almost the same, viz., 5·41. There is very little malarious disease (about 50 to 60 admissions per 1000 of strength), but there has frequently been a good many cases of "continued fever," and dysentery and diarrhœa are usual diseases. Formerly there appears to have been much phthisis, but this is now much less, giving another instance of the decline of this disease, as in so many other stations.

In the years 1837–46, the admissions from tubercular diseases averaged 21 per 1000 per annum, and the deaths 5·45. In the years 1859–66 the admissions from tubercular diseases were 6·6; and the deaths 1·66 per 1000. In 1867 there were no admissions. The health of the troops would have been even better if the causes of the continued fever and dysentery could have been discovered and removed, and if the amount of drunkenness had been less. The returns from St Helena are now combined with those from the Cape of Good Hope.

## SUB-SECTION II.—WEST COAST OF AFRICA.*

The principal stations are Sierra Leone, and Cape-Coast Castle.

The station of Gambia has now been given up, and troops are no longer stationed regularly at Lagos (500 miles from Cape-Coast Castle, and occupied in 1861). In 1875 Sierra Leone, Cape-Coast, and Accra were occupied, and Elmina for a short time. No white troops are employed, except during war-time, as in the Ashanti campaign of 1873.

### *Sierra Leone.*

Strength of garrison, 300 to 500 black troops, with a few officers and non-commissioned officers. Civil population (in 1872), 37,089. Hot season from May to the middle of November; Harmattan wind in December; soil, red sandstone and clay, very ferruginous. There are extensive mangrove swamps to N. and S. Water very pure. The spring in the barrack square contains only 3 to 4 grains per gallon of solids.

This station had formerly the reputation of the most unhealthy station of the army. Nor was this undeserved.

From 1817 to 1837 (twenty years) there were yearly among the troops—

| | |
|---|---|
| Admissions, . . . | 2978 per 1000. |
| Deaths, . . . . | 483 „ |

At the same time, about 17 per cent. of the whole white population died annually.

The chief diseases were malarious fevers, which caused much sickness, but no great mortality; and yellow fever, which caused an immense mortality. Dysentery, chiefly scorbutic, was also very fatal.

The causes of this great mortality were simple enough. The station was looked upon as a place of punishment, and disorderly men, men sentenced for crimes, or whom it was wished to get rid of, were draughted to Sierra Leone. They were there very much overcrowded in barracks, which were placed in the lower part of the town. They were fed largely on salt meat; and being for the most part men of desperate character, and without hope, they were highly intemperate, and led, in all ways, lives of the utmost disorder. They considered themselves, in fact, under sentence of death, and did their best to rapidly carry out the sentence.

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* For a very good account of the topography of the Gold Coast, see Dr R. Clarke's paper in the Transactions Epid. Society, vol. i.

Eventually, all the white troops were removed, and the place has since been garrisoned by one of the West Indian regiments. Of late years, the total white population of Sierra Leone (civil and military) has not been more than from 100 to 200 persons.

The great sickness and mortality being attributable, as in so many other cases, chiefly to local causes and individual faults, of late years Europeans have been comparatively healthy; although from time to time fatal epidemics of yellow fever occur. They are, however, less frequent and less fatal than formerly. The position of the barracks has been altered, and the food is much better. One measure which is supposed to have improved the health of the place, is allowing a species of grass (Bahama Grass) to grow in the streets. The occupiers of the adjacent houses are obliged to keep it cut short, and in good order.

During the four years, 1863–66, there died 8 white non-commissioned officers, in the whole command of the West Coast, out of an average strength of 25, or at the annual rate of 80 per 1000 of strength. Three of the 8 deaths were from liver disease, two from delirium tremens, two from fevers, and one from dysentery. In 1867 two serjeants died, out of 15 white men—one from apoplexy, one from delirium tremens.

Among the black troops serving in Sierra Leone and the Gold Coast, the returns of the ten years 1861–70 give 1283 admissions and 22·49 deaths per 1000. In 1871 the deaths were 15·63 per 1000 from disease. Among the causes of death, tubercular diseases hold the first place, amounting to 7·05 per 1000 of strength. In 1862 phthisis amounted to no less than 12·6 per 1000 of strength, and constituted 43·7 per cent. of all deaths from disease. There were also 9·46 per 1000 of strength deaths from pneumonia. In 1863 the deaths from phthisis were 9·3 per 1000 of strength, and made up 36·3 per cent. of the total deaths. In 1867 the tubercular deaths per 1000 of strength were 17·71 in Sierra Leone, 15·87 at the Gambia, and 12·58 at the Gold Coast and Lagos together. It seems clear, indeed, that in all the stations of the West India corps (black troops), the amount of phthisis is great; in fact, the state of health generally of these regiments requires looking into, as in the West Indies.

In 1862 there were only five cases of intermittent, and eighteen of remittent fever among 317 negroes.

In 1861 some of the troops from Sierra Leone and the Gambia were employed up the Gambia against the Mandingoes, and also against the chiefs of Quiat. In 1863 and 1864 the Ashanti war prevailed. All these wars added to the sickness and mortality, so that these years are not fair examples of the influence of the climate.

### *Gambia.*

No troops have been quartered here of late years, and it has been in contemplation to abandon the station. It is much more malarious than any of the others. The drinking-water is bad; all barrack and sewage arrangements are imperfect. Yellow fever from time to time is very destructive. In 1859 two out of four European serjeants, and in 1860 three medical officers, died of yellow fever. Among the black troops in 1859–65 the admissions were 1169·8, and the deaths 29·97 per 1000 of strength.

As at Sierra Leone, phthisis and other diseases of the lungs caused a large mortality among the negroes. In 1861 phthisis gave five deaths out of a strength of 421, or at the rate of 11·6 per 1000 strength; and pneumonia gave four deaths, and acute bronchitis three, or (together) at the rate of 16·24 per 1000 of strength. Phthisis, pneumonia, and bronchitis gave nearly 60 per cent. of all deaths from disease. This was higher than in previous years; but in 1862 phthisis gave 14·35 deaths per 1000 of strength, and constituted 75 per cent. of the whole number of deaths. There was, however, no pneumonia or bronchitis in that year. In 1856 the tubercular class gave 9·53 deaths per 1000. In 1863, however, there were no deaths from phthisis. Although the period of observation is short, it can hardly be doubted that here, as elsewhere in the stations occupied by the West Indian regiments, some causes influencing the lungs prejudicially are everywhere in action. It is probably to be found in bad ventilation of the barracks.

Among the few white residents at the Gambia, diarrhœa, dysentery, and dyspepsia appear to be common. These, in part, arise from the bad water; in part from dietetic errors (especially excess in quantity), and want of exercise and attention to ordinary hygienic rules.

### *Cape-Coast Castle* (*Gold Coast*).

Garrison, 300 to 400 (black troops).

This station has always been considered the most healthy of the three principal places. It is not so malarious as even Sierra Leone, and much less so than the Gambia, and has been much less frequently attacked with yellow fever. Dysentery and dyspepsia are common diseases among the white residents. Among the black troops the prevalence of phthisis, pneumonia, and bronchitis is marked, though less so, perhaps, than at the other two stations.

One peculiarity of the station is the prevalence of dracunculus. This is uncommon at Sierra Leone, and at the Gambia. It is, on the other hand, very frequent at Cape-Coast Castle.

*Admissions from Guinea-Worm, per* 1000 *of Strength.*

| GARRISONS. | 1860. | 1861. | 1862. | 1863. |
|---|---|---|---|---|
| Sierra Leone, . . . . . | 2·6 | ... | ... | 11·62 |
| Gambia, . . . . . . | ... | ... | ... | ... |
| Cape-Coast Castle, . . . | 246 | 285 | 115 | 12·8 |
| Lagos, . . . . . . . | ... | ... | 88 | ... |

The investigation of the cause of dracunculus at Cape-Coast Castle is one which would well repay the trouble, so abundant is the material of observation; it would probably clear up the still doubtful points on the mode of ingress.*

### *Hygiene on the West Coast.*

There is no doubt that attention to hygienic rules will do much to lessen the sickness and mortality of this dreaded climate. In fact, here as elsewhere, men have been contented to lay their own misdeeds on the climate. Malaria has, of course, to be met by the constant use of quinine during the whole period of service. The other rules are summed up in the following quotation from Dr Robert Clarke's paper,† and when we reflect that this extract expresses the opinion of a most competent judge on the effect of climate, we must allow that, not only for the West Coast, but for the West Indies, and for India, Dr Clarke's opinions on the exaggeration of the effect of the sun's rays and exposure to night air, and his statement of the necessity of exercise, are full of instruction:—

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* For anybody interested in the investigation of the anatomy of the dracunculus, Dr Bastian's paper in the Linnean Transactions (1863) can be recommended.

† Trans. of the Epidem. Soc. vol. i. pp. 123, 124.

"Good health may generally be enjoyed by judicious attention to a few simple rules. In the foremost rank should be put *temperance*, with regular and industrious habits. European residents on the Gold Coast are too often satisfied with wearing apparel suited to the climate, overlooking the fact that exercise in the open air is just as necessary to preserve health there as it is in Europe. Many of them likewise entertain an impression that the sun's rays are hurtful, whereas in nine cases out of ten the mischief is done, not by the sun's rays, but by habits of *personal economy*. Feeling sadly the wearisome sameness of life on this part of the coast, recourse is too frequently had to stimulants, instead of resorting to inexhausting employments, the only safe and effectual remedy against an evil fraught with such lamentable consequences. Europeans also bestow too little attention on ventilation, far more harm being done by close and impure air during the night than is ever brought about by exposure to the night air.

"Much of the suffering is occasioned by over-feeding." (P. 124.)*

## SUB-SECTION III.—CAPE OF GOOD HOPE.

Garrison, about 3000 men.

The chief stations are Cape Town (about 45,000 inhabitants), Graham's Town, King William's Town, Port Elizabeth, Algoa Bay, and several small frontier stations. At Natal there is also a small force. The climate is almost everywhere good; the temperature is neither extreme nor very variable; the movement of air is considerable.

At Cape Town the mean annual temperature is 67°, with a mean annual range of about 38°.

| YEARS. | Total Deaths. | Admissions. | Mean Daily Sick. | Days in Hospital to each Sick Man. |
|---|---|---|---|---|
| 1860-69—(10 years), . . | 10·87 | 973·3 | 50·24 | 18·83 |
| 1869-74—(5 years), . . | 11·15 | 1022·1 | ... | ... |
| †1875, . . . . . . . . | 7·30 | 775·6 | 37·68 | 17·73 |

Malarious diseases are very uncommon. Continued fevers (probably typhoid) are seen and are rather common, though not very fatal. In 1859–66 they gave a mortality of 1·25 per 1000. In 1869–74 only 0·35 per 1000. In the earlier periods dysentery and diarrhœa were very common; they are now less so; in many cases, especially in the small frontier stations, they were clearly owing to bad water.

Ophthalmia has prevailed rather largely, especially in some years; there is a good deal of dust in many parts of the colony, and it has been attributed to this; the disease is probably the specific ophthalmia (grey granulations), and is propagated by contagion. Whether it had its origin in any catarrhal condition produced by the wind and dust, and then became contagious, is one of those moot points which cannot yet be answered.

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* Considerable interest in this part of the work was roused by the occurrence of the Ashanti War of 1873, for an admirable account of which see the Army Medical Reports, vol. xv., where Sir Anthony D. Home gives a full medical history of the operations carried on. The excellent hygienic arrangements enabled the arduous work of the expedition to be accomplished with a comparatively small loss. But the few casualties in action compared with the deaths by disease show by contrast how much more deadly were the forces of nature than those of the enemy. 26 officers died, of whom only five were killed or died of wounds: 18 men were killed (white troops), whilst 40 died of disease; of the West Indian troops (black) only 1 was killed, whilst 41 died of disease. For analysis of soil of Gold Coast see Army Med. Reports, vol. xiv., p. 284, and for some account of the drinking water, see papers by Dr J. D. Fleming in vols. xiv. and xv.

† Including the detachment at St Helena.

The Cape has always been noted for the numerous cases of muscular rheumatism. Articular rheumatism is not particularly common. There is also much cardiac disease. The prevalence of this affection has been attributed to the exposure and rapid marches in hill districts during the Kaffir wars. In 1863 there was, however, less rheumatism than usual.

Taking the years 1859–66 as expressing tolerably fairly the effect, *per se*, of the station, we find that the whole colony gave 18·3 admissions and 1·90 deaths per 1000 of strength from diseases of the circulatory organs. In 1869–74 the admissions were 13·1, and the deaths 1·68; in 1875 they were 13·1 and 1·45 respectively.

Dr Lawson* has lately contributed a valuable paper on this subject. He finds the death rate from diseases of the organs of circulation (mean of seven years, 1859–65) as 1·91 per 1000 of strength. This is higher than at any other foreign station, as will be seen from the table copied by Dr Lawson.

*Mortality from Diseases of the Circulatory Organs.*

| | Ratio per 1000 of Strength. | | Ratio per 1000 of Strength. | | Ratio per 1000 of Strength. |
|---|---|---|---|---|---|
| Cape of Good Hope, | 1·91 | Bombay, . . . | ·80 | Malta, . . . . . | ·53 |
| New Zealand, . | 1·18 | Bengal, . . . . | ·86 | Gibraltar, . . . | ·70 |
| Australia, . . . | 1·72 | South China, . . | 1·16 | Bermuda, . . . | 1·25 |
| Mauritius . . . | ·53 | West Indies, . . | 1·02 | Nova Scotia, . . | ·84 |
| St. Helena, . . | ·31 | Jamaica, . . . | ·85 | Canada, . . . . . | 1·19 |
| Ceylon, . . . | 1·11 | Ionia, . . . . . | ·84 | Home, . . . . . | ·93 |
| Madras, . . . | 1·12 | | | | |

This table shows an extreme diversity, hardly to be reconciled with differences of climate or duties. In the years[1] 1869–74 the death rate was 1·68, and was exceeded by that of the Mauritius, 2·29, and that of Madras, 1·99. In 1875 the rate at the Cape was only 1·45, while Ceylon showed 3·87, Bermuda 2·63, and Madras 2·05; Mauritius returning no death.

Scurvy formerly prevailed much at the Cape, particularly in the Kaffir wars.

Venereal diseases have of late years have been very common. The average admissions from "enthetic" diseases in 1859–66 were 248·5, and in 1867 they were 438·3 per 1000 of strength in the whole colony. In Cape Town alone, where facilities for promiscuous intercourse are greater, they are even more numerous.† Some diminution has taken place in recent years.

The Cape has always been considered a kind of sanitarium for India. Its coolness and the rapid movement of the air, the brightness and clearness of the atmosphere, and the freedom from malaria, probably cause its salubrity. It has been supposed that it might be well to send troops to the Cape for two or three years before sending them on to India. This plan has, I believe, never been perfectly tried; but in the case of regiments sent on hurriedly to India on emergency it has been said that the men did not bear the Indian climate well. Probably they were placed under unfavourable conditions, and the question is still uncertain.

As a convalescent place for troops who have been quartered in a malarious district it is excellent.‡

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* Dr Lawson has published a memoir on this subject (Army Medical Report, vol. v. p. [illegible]), to which reference may be made.

† Army and Med. Depart. Report, vol. viii. p. 548.

‡ See effect on the 59th Regiment in the Army Medical Report for 1859, p. 99.

## SECTION VI.

## MAURITIUS.

Garrison, about 1500 to 2000 men. Civil population (in 1875), 344,802.

Mauritius in the eastern has been often compared with Jamaica in the western seas. The geographical position as respects the equator is not very dissimilar; the mean annual temperature (80° Fahr.) is almost the same; the fluctuations and undulations are more considerable, but still are not excessive; the humidity of air is nearly the same, or perhaps a little less; the rainfall (66 to 76 inches) is almost the same; and the physical formation is really not very dissimilar. Yet, with all these points of similarity in climatic conditions, the diseases are very different.

Malarious fever was formerly not nearly so frequent as in Jamaica, and true yellow fever is quite unknown; Mauritius, therefore, has never shown those epochs of great mortality which the West Indies have had. Hepatic diseases, on the other hand, which are so uncommon in the West Indies, are very common in the Mauritius. For example, in 1859 there were 47 cases of acute and chronic hepatitis in 1254 men, while in Jamaica there was one case out of 807 men. In 1860 there were 31 admissions from acute hepatitis out of 1886 men; in Jamaica, there was not a single case. In 1862 there were 12 cases of acute, 11 of chronic hepatitis, and 72 cases of hepatic congestion, out of 2049 men; in Jamaica, in the same year, there was only 1 case of acute hepatitis out of 702 men. This has always been marked; is it owing to an error in diagnosis, or to differences in diet? It can scarcely be attributed to any difference in climate. In 1863 the difference was less marked, but was still evident. In later years, however, there has been considerable diminution: in 1872 there were only 4 cases of hepatitis, and in 1873 only 2. Since that year no detailed statistics have been published.

In 1866–67 a very severe epidemic fever prevailed in the Mauritius, which offers many points of interest. As already noted, the Mauritius has till lately been considered to be comparatively free from malaria. All the older writers I have consulted state this, and it is apparent from all the statistical returns. Deputy-Inspector Dr Francis Reid, in a late report,* mentions that he had served ten years in the Mauritius, and had looked over the records of the troops for twenty-four years. He found some records of intermittents, but he traced all these to foreign sources, viz., troops coming from India, China, or Ceylon, and presenting cases of relapses.

For the first time, in the latter months of 1866 and the commencement of 1867, malarious fevers of undoubted local growth appeared on the western side of the island.

The causes of this development are traced by Dr Reid, and also by Surgeon-Major Small and Assistant-Surgeon W. H. T. Power, in some very careful Reports.† During the last few years a large amount of forest land has been cleared, and there has been much upturning of the soil; coincidently the rainfall has lessened, and the rivers have become far less in volume. At the same time, there has been a large increase of population; a great defilement of the ground in the neighbourhood of villages and towns, so that in various parts of the island there has been a constant drainage down of filth of all kinds (vegetable and animal) into a loose soil of slight depth, resting on impermeable rock, which forms a great deal of the western seaboard. In 1866–67 there occurred an unusually hot season, and again a deficient rainfall. This seems to have brought into active operation the conditions which had been gradually increasing in intensity for some years. The development of the malaria was not so much on the regular marshy ground as on the loose contaminated soil already noticed.

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* Letter to the Director-General, Feb. 1867.

† Annual Report on the District Prison Hospitals (in 1867), Mauritius, 1868. On the Malarial Epidemic Fever of the Mauritius, Army Med. Dep.

That the fever which in 1866–67 became so general was of malarious type, is proved by a large amount of evidence on the spot from both military and civil practitioners, and from the fact that many soldiers returned to England and had at home relapses of decided paroxysmal fevers. Dr Maclean also informs me that he has seldom seen spleens so enlarged as among the invalids from this fever, who arrived at Netley.

But in some respects this fever presented characters different from common paroxysmal fevers. There was no very great mortality among the troops, but it was excessively fatal among the inhabitants of Port Louis and many other towns and villages. It also lasted for many months, and was attended in many cases with symptoms not common in common paroxysmal fevers, viz., with yellowness of the skin and with decided relapses, closely resembling in these respects the common relapsing fever. Mixed up with it also was decided typhoid fever. The question whether the great bulk of the epidemic was a purely paroxysmal or malarious fever, with an independent subordinate outbreak of typhoid fever, or whether it was a composite affection like the "typho-malarial fever" of the American war,* or was mixed up with the contagious "Indian jail fever" imported by Coolies, is not a matter very easy to decide. The officers best qualified to judge (Drs Reid, Small, and Power) look upon it as a purely malarious disease, and have expressed themselves very strongly on this point.†

This much seems certain, that in various parts of the island the loose, porous, shallow soil had been gradually becoming more and more impure with vegetable matters, and in some cases with animal excreta; that there had been a gradual diminution of the subsoil water, and that this reached its maximum in 1866, when the rains failed, and the hot season was prolonged. There coincided, then, an unusual impurity of soil, lowered subsoil water, consequent increased access of air, and heightened temperature. Under these conditions, a usually non-malarious soil gave rise to an epidemic fever, which was characterised (chiefly at any rate) by the symptoms referred to the action of marsh miasmata, and was curable by quinine. The admissions for paroxysmal fevers alone were, in 1875, 585·5 per 1000, and in 1869–75 (five years) 722·3 per 1000 as a mean.

In the Mauritius, as in Jamaica, a "continued fever" is not uncommon; this is now being returned in part as typhoid.‡ It has occasionally been imported. There are fevers vaguely named "bilious remittent," "Bombay fever," "Coolie fever," &c. The last term denotes the communicable fever so common in the jails in the Bengal Presidency. It prevailed in the jails in the Mauritius in 1863 and 1864, among the Hindoos. The "Bombay fever" is probably typhoid. Dysentery and diarrhœa have largely prevailed, but are now becoming less frequent, though still in too great amount. In this respect Jamaica now contrasts very favourably with the Mauritius; thus, in 1860, there was altogether 213 admissions per 1000 of dysentery and diarrhœa, and 6·8 deaths per 1000; in Jamaica, in the same year, there was not a single admission from dysentery, and only 19 from diarrhœa, among 594 men, and no death. Cholera has prevailed five times—first in 1819; not afterwards till 1854; then again in 1856, 1859, and 1861. (It appears to have been imported in all these cases.) Formerly there was a large mortality from lung diseases; now, as in Jamaica, this entry is much less, not more than half that of former days. The deaths from phthisis per 1000 of strength were, in 1860, ·521; in 1861, 1·03; in 1862, 1·94 (but in this year 11 men were invalided for phthisis); and in 1863, 2; in 1875 no death was recorded. Venereal (enthetic) diseases formerly gave about 110 to 130 admissions per 1000 of strength, but they are now greatly diminished. Ophthalmia prevails moderately; to nothing like the same extent as at the Cape.

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* As described by Woodward, Camp Diseases of the United States Armies, by J. J. Woodward, M.D., Philadelphia, 1863, p. 77.

† The two latter gentlemen say, *op. cit.* p. 458—"It was entirely of malarious origin, and in every form, we might say, perfectly curable by the administration of quinine in large doses." These observers entirely deny that it had any contagious properties.

‡ Dr Reid has no doubt of the frequent occurrence of typhoid for many years. He mentions an interesting fact, viz., that patients with true enteric fever were also affected with the malarious epidemic fever; this latter was, however, easily curable by quinine, but the typhoid fever, which was also present, was quite unaffected.

In the earlier periods, owing to the absence of yellow fever, the mortality of the Mauritius contrasted favourably with that of Jamaica, but now it is greater. In 1876 the death-rate of the Mauritius was 6·81, that of the West Indies generally only 3·68.

*Per* 1000 *of Strength.*

| YEARS. | Loss of Strength. | | | Loss of Service. | | |
|---|---|---|---|---|---|---|
| | Deaths (all Causes). | Deaths from Disease. | Invaliding. | Admissions. | Mean Daily Sick. | Days in Hospital to each Sick Man. |
| 1817–36, . . . | 30·5 | ... | ... | 1249 | 68 | 20 |
| 1861–70 (10 years, . | 20·17 | ... | ... | 1056·5 | ... | ... |
| 1865–74 (10 years, . | 18·97 | ... | 44·15 | 1419·4 | 53·58 | 13·76 |
| 1875, . . . | 14·46 | ... | 50·60 | 1322·9 | 40·92 | 11·26 |

## SECTION VII.

## CEYLON.*

Garrison, 800 to 1000 white troops; and about 100 gun-lascars (black). Population, 2,400,000 (in 1871), including about 5000 Europeans. The stations for the white troops are chiefly Galle, Colombo, Kandy, and Trincomalee, with a convalescent station at Newera Ellia (6200 feet above sea-level). The black troops are more scattered, at Badulla, Pultan, Jaffna, &c.

*Geology.*—A considerable part of the island is composed of granite, gneiss, and hornblende granite rocks; these have become greatly weathered and decomposed, and form masses of a conglomerate called "cabook," which is clayey like the laterite of India, and is used for building. The soil is derived from the debris of the granite; is said to absorb and retain water eagerly. In some parts, as at Kandy, there is crystalline limestone.

*Climate.*—This differs, of course, exceedingly at different elevations. At Colombo, sea-level, the climate is warm, equable, and limited. Mean annual temperature about 81°. Mean temperature—April, 82°·70; January, 78°·19; amplitude of the yearly fluctuation = 4°·51. April and May are the hottest months; January and December the coldest. Amount of rain about 74 inches; the greatest amount falls in May with the S.W. monsoon (about 13 to 14 inches); and again in October and November with the N.E. monsoon (about 10 to 12 inches) in each month. Rain, however, falls in every month, the smallest amount being in February and March. The heaviest yearly fall ever noted was 120 inches. The relative humidity is about 80 per cent. of saturation. The S.W. monsoon blows from May to September, and the N.E. monsoon during the remainder of the year, being unsteady and rather diverted from its course (long-shore wind) in February and March. The mean horizontal movement during the year 1872 was 125 miles; in 1870 it was 139 miles, or rather under 6 miles an hour.

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* For a full account, see Sir E. Tennent's Ceylon.

At Kandy (72 miles from Colombo, 1676 feet above sea-level), the mean temperature is less, 3° to 5°; the air is still absolutely humid, though relatively rather dry. At 9·30 A.M. the mean annual dew-point is 70°·4, and at 3·30 P.M. it is 71°·54. This corresponds to 8·11 and 8·42 grains in a cubic foot of air; as the mean temperature at these times is 76·37 and 79·27, the mean annual relative humidity of the air at 9·30 A.M. and 3·30 P.M. is 71 and 63 per cent. of saturation. The heat is oppressive, as Kandy lies in a hollow, as in the bottom of a cup.

At Newera Ellia (48 miles from Kandy, 6210 feet high) is a large tableland, where, since 1828, some Europeans have been stationed; the climate is European, and at times wintry; the thermometer has been as low as 29°, and white frosts may occur in the early morning in the coldest months. The mean annual temperature is about 59°.*

In the dry season (January to May) the thermometer's daily range is excessive; the thermometer may stand at 29° at daybreak, and at 8 A.M. reach 62°; at mid-day it will mark 70° to 74°, and then fall to 50° at dark. In one day the range has been from 27° to 74° = 47°. The air is very dry, the difference between the dry and wet bulbs being sometimes 15°. Assuming the dry bulb to mark 70°, this will give a relative humidity of only 38 per cent. of saturation; the barometer stands at about 24·25 inches. Although the diurnal range of temperature is thus so great, it is equable from day to day.

Such a climate, with its bright sun and rarefied air, an almost constant breeze, and an immense evaporating force, seems to give us, at this period, the very beau ideal of a mountain climate.

In the wet season (May or June to November) all these conditions are reversed. The mean thermometer of 24 hours is about 59°, and the range is only from 56° at daybreak to 62° at midday; during the height of the monsoon, there are about 30 inches of rainfall, and sometimes as much as 70; the air is often almost saturated. The mean of three years (1870–72) gives no less than 94½ inches.

Two more striking climatic differences than between January and June can hardly be conceived, yet it is said Newera Ellia is equally healthy in the wet as in the dry season; the human frame seems to accommodate itself to these great vicissitudes without difficulty. The most unhealthy times are at the changes of the monsoons.

Although there is some moist and even marshy ground near the station, ague is not common, though it is seen; the temperature is too low in the dry season, and the fall of rain too great in the wet. Typhoid fever is seen, and may be combined with periodic fever (Massy, in "Army Med. Reports," vol. viii. p. 499). It is said that dyspepsia, hepatic affections, and nervous affections are much benefited; phthisis is so to some extent, but, it would appear, scarcely so much as European experience would have led us to expect; rheumatism does not do well, nor, it is said, chronic dysentery; but it would be very desirable to test this point, as well as that of the influence on phthisis carefully. The so-called "hill diarrhœa" of India prevailed in 1865, though before this it was unknown. Dysentery has sometimes prevailed, and is caused in some cases by bad water (Massy).

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* I have taken many of these facts from an excellent Report by Assistant-Surgeon R. A. Allan, which I had the advantage of reading, as well as from Sir E. Tennent's book.

The soil of Newera Ellia is chiefly decomposed gneiss; it is described by Dr Massy as being as hygroscopic as a sponge; the contents of cesspools easily traverse it, and the removal of excreta demands great care.

The neighbouring Horton Hills are said to be even better than Newera Ellia itself. Probably in the whole of Hindustan, a better sanitary station does not exist. It is inferior, if it be inferior, only to the Neilgherries, and one or two of the best Himalayan stations.

*Sickness and Mortality*[*] *of Europeans per* 1000 *of Strength.*

| | Deaths. | Admissions. | Mean Daily Sick. | Duration of Sickness. |
|---|---|---|---|---|
| 1860–69 (10 years), . . | 23·75 | 1424·9 | 66·52 | 16·6 days |
| 1869–74 (6 years), . . | 17·72. | 1112·6 | ... | ... |
| 1875, . . . . . . | 13·56 | 730·3 | 46·11 | 21·57 ,, |

*Influence of Age on Mortality.*

| | Under 20 Years. | 20 and Under 25. | 25 and Under 30. | 30 and Under 35. | 35 and Under 40. | 40 and Over. |
|---|---|---|---|---|---|---|
| 1864–73, . . . | 5·79 | 15·89 | 28·81 | 26·50 | 50·25 | 173·91 |

Among the black troops, now reduced to about 100 altogether, in Ceylon (1860–69) the admissions averaged 1011, and the deaths 15·17, per 1000 of strength. In 1870 the total mortality was 9·44 per 1000. The chief causes of admissions were paroxysmal fevers, and of deaths, cholera, dysentery, and paroxysmal fevers. "Continued fever" also figures among the returns, but was less common in the later years. The average number constantly sick was about 32, and the duration of the cases 10 or 11 days.

In Ceylon, therefore, the black troops were healthier than the white, contrasting in this remarkably with the West Indies.

In conclusion, it may be said that much sanitary work still remains to be done in Ceylon before the state of the white troops can be considered satisfactory.

## SECTION VIII.

## INDIA.

About 60,000 Europeans are now (1877) quartered in India, and there is in addition a large native army. In this place the Europeans will be chiefly referred to, as it would require a large work to consider properly the health of the native troops.[†]

The 60,000 Europeans are thus distributed:—About 38,000 are serving in the Bengal Presidency, which includes Bengal proper, the North-West Provinces, the Punjab, and the Trans-Indus stations. About 11,500 are serving in the Madras Presidency, which also garrisons some parts of the coast of Burmah, and sends detachments of native troops to the Straits of Malacca. About 10,500 are serving in the Bombay Presidency.* The troops consist of all arms.

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[*] In 1876 the death-rate was only 7·43.

[†] The general principles of hygiene are of course to be applied in the case of the natives of Hindustan, and so far there is nothing unusual. In the chapter on FOOD I have purposely included the chief articles of diet; the question of water and air is the same for all nations, and other hygienic rules of clothing or exercise can be easily applied to them. But their health is much influenced by their customs, which are in many races peculiar. The only proper way of treating such a subject would be by a work on the hygiene of India generally, including the native army as a branch of the community.

These men are serving in a country which includes nearly 28° of lat. and 33° of long., and in which the British possessions amount to 1,465,322 square miles. Stretching from within 8° of the equator to 13° beyond the line of the tropics, and embracing countries of every elevation, the climate of Hindustan presents almost every variety; and the troops serving in it, and moving from place to place, are in turn exposed to remarkable differences of temperature, degrees of atmospheric humidity, pressure of air, and kind and force of wind, &c.

Watered by great rivers which have brought down from the high lands vast deposits in the course of ages, a considerable portion of the surface of the extensive plains is formed by alluvial deposit, which, under the heat of the sun, renders vast districts more or less malarious; and there are certain parts of the country where the development of malaria is probably as intense as in any part of the world. A population, in some places thickly clustered, in others greatly scattered, formed of many races and speaking many tongues, and with remarkably diverse customs, inhabits the country, and indirectly affects very greatly the health of the Europeans.

Cantoned over this country, the soldiers are also subjected to the special influences of their barrack life, and to the peculiar habits which tropical service produces.

We can divide the causes which act on the European force into four subsections—

1. The country and climate.
2. The diseases of the natives.
3. The special hygienic conditions under which the soldier is placed.
4. The service, and the individual habits of the soldier.

### SUB-SECTION I.—THE COUNTRY AND CLIMATE.

The geological structure and the meteorological conditions are, of course, extremely various, and it is impossible to do more than glance at a few of the chief points.

1. *Soil.*†—There is almost every variety of geological structure. In the north-west, the vast chain of the Himalayas is composed of high peaks of granite and gneiss; while lower down is gneiss and slate, and then sandstone and diluvial detritus. Stretching from Cape Comorin almost to Guzerat, come the great Western Ghauts, formed chiefly of granite, with volcanic rocks around; and then stretching from these, come the Vindhya and Satpoora Mountains, which are chiefly volcanic, and inclose the two great basins of the Taptee and Nerbudda rivers. Joining on to the Vindhya, come the Aravalli Hills, stretching towards Delhi, and having at their highest point Mount Aboo, which is probably destined to become the great health resort of that part of India.

On the east side, the lower chain of the Eastern Ghauts slopes into the table-land of the Deccan; and at the junction of the Eastern and Western Ghauts come the Neilgherry Hills, from 8000 to 9000 feet above sea-level, and formed of granite, syenite, hornblende, and gneiss. But to enumerate all the Indian mountains would be impossible.

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* For brevity, it is customary to speak of serving in Bengal, Bombay, or Madras, when speaking of the Presidency, so that these names are sometimes applied to the cities, sometimes to the presidencies; but a little care will always distinguish which is meant.

† See Carter's Summary of the Geology of India, in the Journal of the Bombay Asiatic Society's Transactions, 1853.

Speaking in very general terms, the soil of many of the plains may be classed under four great headings.

(*a*) Alluvial soil, brought down by the great rivers Ganges, Indus, Brahmapootra, rivers of Nerbudda, Guzerat, &c. It is supposed that about one-third of all Hindustan is composed of this alluvium, which is chiefly siliceous, with some alumina and iron. *At points it is very stiff with clay*—as in some parts of the Punjab, in Scinde, and in some portion of Lower Bengal. Underneath the alluvial soil lies, in many places, the so-called clayey laterite. Many of the stations in Bengal are placed on alluvial soil.

This alluvial soil, especially when, not far from the surface, clayey laterite is found, is often malarious; sometimes it is moist only a foot or two from the surface; and, if not covered by vegetation, is extremely hot.

As a rule, troops should not be located on it. Whatever be done to the spot itself—and much good may be done by efficient draining—the influences of the surrounding country cannot be obviated. Europeans can never be entirely free from the influences of malaria. There is but one perfect remedy; to lessen the force in the plains to the smallest number consistent with military conditions, and to place the rest of the men on the higher lands.

Somewhat different from the alluvial is the soil of certain districts, such as the vast Runn of Cutch, which have been the beds of inland seas, and now form immense level marshy tracks, which are extremely malarious. The Runn of Cutch contains 7000 square miles of such country.

(*b*) The so-called "regur," or "cotton soil," formed by disintegrated basalt and trap, stretches down from Bundelcund nearly to the south of the peninsula, and spreads over the table-land of Mysore, and is common in the Deccan. It is often, but not always, dark in colour. It contains little vegetable organic matter (1·5 to 2·5 per cent.), and is chiefly made up of sand (70 to 80 per cent.), carbonate of lime (10 to 20 per cent.), and a little alumina. It is very absorbent of water, and is generally thought unhealthy. It is not so malarious as the alluvium, but attacks of cholera have been supposed to be particularly frequent over this soil.

(*c*) Red soil from disintegration of granite. This is sometimes loamy, at other times clayey, especially where felspar is abundant. The clay is often very stiff.

(*d*) Calcareous and other soils scattered over the surface, or lying beneath the alluvium or cotton soil. There are, in many parts of India, large masses of calcareous (carbonate of lime) conglomerate, which is called kunkur. It is much used in Bengal for footpaths and pavements.

In Behar, and some other places, the soil contains large quantities of nitre, and many of the sand plains are largely impregnated with salts.

2. *Temperature.*—There is an immense variety of temperature. Towards the south, and on the sea-coast, the climate is often equable and uniform. The amplitudes of the annual and diurnal fluctuations are small, and in some places, especially those which lie somewhat out of the force of the south-west monsoon, the climate is perhaps the most equable in the world.

At some stations on the southern coast, the temperature of the sun's zenith is lower than at the declination, in consequence of the occurrence of clouds and rain, brought up by the south-west monsoon.

In the interior, on the plateaux of low elevation, the temperature is greater, and the yearly and diurnal fluctuations are more marked. On the hill stations (6000 to 8000 feet above sea-level), the mean temperature is much less; the fluctuations are sometimes great, sometimes inconsiderable.

The influence of winds is very great on the temperature; the sea-winds lowering it, hot land winds raising it greatly.

The temperature in the sun's rays ranges as high as 166° or 170°, but the mean sun rays' temperature is, with great differences in different places, between 130° and 160° at the hottest time of the year.

The air temperature of a few of the principal stations is subjoined, merely to give an idea of the amount of heat in different parts of the country.* Those of the hill stations are given under the proper headings.

*Mean Temperature and Height, above Sea-level, of some of the larger*

| MONTHS. | Calcutta, Fort-William, 8 feet above sea-level. | Punjaub, generally 800 to 900ft. above sea-level. | Peshawur, 1068 feet above sea-level. | Madras, Fort St. George, at sea-level. | Bangalore, 3000 feet above sea-level, 1 yr. only. | Bombay, at sea-level. | Poonah, 1800 feet above sea-level. | Belgaum, 2500 feet above sea-level. |
|---|---|---|---|---|---|---|---|---|
| Mean of year, | 82° | 73° | 74° | 82° | 76° | 80° | 78° | 74° |
| January, | 70 | 54 | 52 | 76 | 69 | 74 | 72 | 72 |
| February, | 75 | 60 | 55 | 78 | 78 | 76 | 75 | 75 |
| March, | 83 | 68 | 65 | 80 | 79 | 80 | 79 | 78 |
| April, | 88 | 77 | 75 | 84 | 79 | 83 | 83 | 81 |
| May, | 89 | 86 | 88 | 87 | 82 | 86 | 85 | 78 |
| June, | 87 | 89 | 91 | 88 | 77 | 83 | 81 | 75 |
| July, | 85 | 87 | 91 | 85 | 77 | 81 | 77 | 73 |
| August, | 85 | 86 | 88 | 85 | 75 | 81 | 76 | 72 |
| September, | 85 | 83 | 84 | 84 | 76 | 80 | 77 | 74 |
| October, | 84 | 76 | 73 | 82 | 75 | 82 | 79 | 74 |
| November, | 78 | 61 | 64 | 79 | 73 | 79 | 76 | 72 |
| December, | 72 | 55 | 56 | 76 | 71 | 76 | 73 | 70 |
| Amplitude of yearly fluctuation (difference between hottest and coldest months), | 19 | 35 | 39 | 12 | 13 | 12 | 13 | 11 |

The increase and the amplitude of the yearly fluctuation is thus seen as we pass to the north, and ascend above sea-level.

In several places there are great undulations of temperature from hot land winds, or from sea or shore breezes, or from mountain currents, which give to the place local peculiarities of temperature.

To get the same mean annual temperature as in England, it would be necessary that 9500 feet be ascended in places south of lat. 20°; between lat. 20° and 26°, 9000 feet; between lat. 26° and 30°, 8700 feet; and north of lat. 30°, 8500.

The mean monthly temperatures would, however, at such elevations, differ somewhat from those of England. Speaking generally, an elevation of 5000 to 6000 feet will give over the whole of India a mean annual temperature about 10° higher than that of England, and with a rather smaller range.

Mr Glaisher has calculated that in the cold months the decrease of temperature is 1°·05 for each 300 feet of ascent, but increases from March to August to 4°·5, and then gradually declines. These results are not accordant with the recent balloon ascents in this climate.

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* These are taken from Mr Glaisher's very excellent report in the Indian Sanitary Commission, which must be consulted for fuller details. Very full meteorological returns are now being given in the Reports of the Sanitary Commissioners for the three presidencies, and in a few years these will supersede Mr Glaisher's tables.

*Humidity.*—The humidity of different parts of India varies extremely; there are climates of extreme humidity—either flat, hot plains, like Lower Scinde, where, without rain, the hot air is frequently almost saturated, and may contain 10 or 11 grains of vapour in a cubic foot; or mountain ranges like Dodabetta, in Madras, 8640 feet above sea-level, where, during the rainy season, the air is also almost saturated; a copious rain, at certain times of the year, may make the air excessively moist, as on the Malabar coast, the coast of Tenasserim, or on the Khasyah Hills, where the south-west monsoon parts with its vapours in enormous quantities.

On the other hand, on the elevated table-land of the interior, and on the hot plains of North-West India, during the dry season, or in the places exposed to the land winds at any part, the air is excessively dry. In the Deccan the annual average of the relative humidity is only 55 per cent. of saturation (Sykes). Mr Glaisher has given the humidity of many places. I extract a few stations:—

*Mean Humidity per cent.*

| | Fort William. | Madras, Fort St George. | Bombay. | Benares. | Meerut. | Peshawur. | Bellary. | Secunderabad. | Poonah. | Kurrachee. | Belgaum. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Maximum, . | 81 | 79 | 85 | 94 | 84 | 73 | 76 | 84 | 79 | 80 | 84 |
| ,, Minimum, . | 59 | 61 | 67 | 44 | 54 | 41 | 40 | 40 | 42 | 48 | 43 |
| Yearly Mean, . | 68 | 72 | 73 | 69 | 67 | 55 | 56 | 54 | 53 | 62 | 64 |

The mean relative humidity at Greenwich is 82, varying from 89 in December and January to 76 in July. Calcutta, therefore, with a mean yearly humidity of 68 per cent. of saturation, is, as far as relative humidity (*i.e.*, evaporating power) goes, less moist than England, and the evaporating power is also increased by the higher temperature.

*Rain.*—The amount of rain and the period of fall vary exceedingly in the different places. It is chiefly regulated by the monsoons.

When the south-west monsoon, loaded with vapour, first strikes on high land, as on the Western Ghauts, on the Malabar coast, or on the mountains of Tenasserim, and especially on the mountains of the Khasyah Hills, at some points of which it meets with a still colder air, a deluge of rain falls; as, for example, at Cannanore (Malabar), 121 inches; Mahableshwur, 253 inches; Moulmein (Tenasserim), 180 inches; Cherrapoonjee (Khasyah Hills), 600 inches. On the other hand, even in places near the sea, if there is no high land, and the temperature is high, scarcely any rain falls; as in Aden, on the south coast of Arabia, or at Kota, in Scinde, where the amount is only 1·8 annually, or Kurrachee, where the yearly average is only 4·6 inches. Or in inland districts, the south-west monsoon, having lost most of its water as it passed over the hills, may be comparatively dry, as at Nusserabad, where only 15·8 inches fall per annum, or Peshawur, where there are 13·7 inches annually.

The yearly amount of rain in some of the principal stations is

| | Average. | | Average. |
|---|---|---|---|
| Calcutta, | 56·8 | Madras Presidency— | |
| Madras, | 50 | Bellary, | 21·7 |
| Bombay, | 72·7 | Bangalore, | 35 |
| Bengal Presidency— | | Trinchinopoly, | 30·6 |
| Dinapore, | 31·1 | Secunderabad, | 34·6 |
| Berhampore, | 49·8 | | |
| Benares, | 37·4 | | |
| Ghazeepore, | 41·4 | Bombay Presidency— | |
| Azimghur, | 40 | Belgaum, | 51·5 |
| Agra, | 27·9 | Poonah, | 27·6 |
| Delhi, | 25·1 | Neemuch, | 34·1 |
| Meerut, | 18 | Kamptee, | 21·8 |
| Punjab, | 56·6 | | |

*Winds.*—The general winds of India are the north-east monsoon, which is, in fact, the great north-east trade wind, and the south-west monsoon, a wind caused by the aspiration of the hot earth of the continent of Asia, when the sun is at its northern declination. During part of the year (May to August) the south-west monsoon forces back the trade-wind or throws it up, for at great altitudes the north-east monsoon blows through the whole year, and the south-west monsoon is below it. But, in addition, there are an immense number of local winds, which are caused by the effect of hills on the monsoons, or are cold currents from hills, or sea breezes, or shore winds caused by the contact of sea breezes and other winds, or by the first feeble action of the south-west monsoon before it has completely driven back the north-east trade. The south-west monsoon is in most of its course loaded with vapour; the north-east is, on the contrary, a colder and drier wind, except when at certain times of the year, in passing over the Indian Ocean, it takes up some water, and reaches the Coromandel Coast and Ceylon as a moist and rain-carrying wind.

The hot land winds are caused by both the south-west monsoon, after it has parted with its moisture and got warmed by the hot central plains, and the north-east monsoon; the temperature is very great, and the relative humidity very small, the difference between the dry and the wet bulb being sometimes 15° to 25° Fahr.

*Pressure of the Air.*—On this point little need be said. The barometer is very steady at most sea-coast stations, with regular diurnal oscillations, chiefly caused by alteration in humidity. An elevation of 5000 feet lowers the barometer to nearly 25 inches.

*Electricity.*—On this point few, if any, experiments have been made; the air is extremely charged with electricity, especially in the dry season, and the dust-storms are attended with marked disturbance of the electrometer.*

*Effects of Climate.*—The estimation of the effects of such various climates is a task of great difficulty. Long-continued high temperature, alternations of great atmospheric dryness and moisture, rapidly moving and perhaps dry and hot air, are common conditions at many stations; at others, great heat during part of the year is followed by weather so cold that even in England it would be thought keen. When to these influences the development of malaria is added, enough has been said to show that, *a priori*, we can feel certain that the natives of temperate climates will not support such a climate without influence on health, and the selection of healthy spots for troops is a matter of the greatest moment as affects both health and comfort. This much being said, it must at the same time be asserted that, malaria excepted, the influences of climate are not the chief causes of sickness.

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* See Baddeley's Whirlwinds and Dust Storms of India (1860), for a very good account of these singular storms.

The location of troops should be governed by two or three conditions—1. Military necessities; 2. Convenience; 3. Conditions of health. The second of these conditions is, however, a mere question of administration; every place can be made convenient in these days of railway and easy locomotion. Military necessity and health are the only real considerations which should guide our choice. The vital military points must be held with the necessary forces, and then the whole of the remaining troops can be located on the most healthy spots.

These spots cannot be in the plains. Let any one look at a geological map of India, and see the vast tract of alluvial soil which stretches from the loose soil of Calcutta, formed by the deposit of a tidal estuary, up past Cawnpore, Delhi, to the vast plains of the Punjab, Scinde, and Beloochistan. The whole of that space is more or less malarious, and will continue to be so until, in the course of centuries, it is brought into complete tillage, drained, and cultivated. Moreover, heat alone without malaria tells upon the European frame, lessens the amount of respiration and circulation, and lowers digestive power (see CLIMATE, page 433).

In looking for healthy spots, where temperature is less tropical, and malarious exhalations less abundant, there are only two classes of localities which can be chosen—seaside places and highlands.

*Seaside Places.*—The advantages of a locality of this kind are, the reduction in temperature caused by the expanse of water, the absence of excessive dryness of the air, and the frequent occurrence of breezes from the sea. All these advantages may be counteracted by the other features of the place; by a damp alluvial soil, bad water, &c.

It does not appear that many eligible places have yet been found, and as a substitute in Bengal, the Europeans from Calcutta sometimes live on board a steamer anchored off the sandheads, thus literally carrying out a suggestion of Lind in the West Indies a century ago.

In the Bay of Bengal, Waltair, in the northern division of Madras, is one of the best.* Cape Calimere (28 miles south of Nagapatam) also appears to have many advantages (Macpherson). On the opposite coast, Cape Negrais on the Burmese coast, was pointed out as long ago as 1825, by Sir Ranald Martin, as a good marine sanitarium, and Amherst in Tenasserim, and some of the islands down the coast towards Mergui, are beautiful spots for such a purpose, being, however, unfortunately, at a great distance from the large military stations, and not being well supplied with food.

On the Bombay side, at Sedashagur or Beitkul Bay, between Mangalore and Goa, a spur of the Western Ghauts projects into the sea for upwards of a mile, and forms an admirable sea-coast sanitarium (Macpherson).

All these sea-coast stations seem adapted for organic visceral affections and dysentery, but they are not so well calculated for permanent stations for healthy men. Probably they are rather sanitaria than stations.

*Highlands.*—The location of troops on the hills or on elevated table-lands has long been considered by the best army medical officers as the most important sanitary measure which can be adopted. Not only does such a location improve greatly the vigour of the men, who on the hill stations preserve the healthy, ruddy hue of the European, but it prevents many diseases. If properly selected, the vast class of malarious diseases disappears;

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* Evidence of Dr Maclean in India Report, p. 139.

liver diseases are less common, and bowel complaints, in some stations at any rate, are neither so frequent nor so violent. Digestion and blood nutrition are greatly improved. Moreover, a proper degree of exercise can be taken, and the best personal hygienic rules easily observed.

Indian surgeons appear, however, to think the hill stations not adapted for cardiac and respiratory complaints; it is possible that this objection is theoretical. The latest European experience is to the effect that phthisis is singularly benefited by even moderate, still more perhaps by great elevation; that anæmia and faulty blood nutrition are cured by high positions with great rapidity, and that if the elevation be not too great (perhaps not over 3000 feet) even chronic heart diseases are improved. In some of the hill stations of India bowel complaints were formerly so frequent as to give rise to the term "hill diarrhœa." The elevation was credited with an effect which it never produced, for, not to speak of other parts of the world, there are stations in India itself (Darjeeling, for example) as high as any other, where the so-called hill diarrhœa was unknown. At Newera Ellia, in Ceylon, too, if the simple condition of mountain elevation could have produced diarrhœa, it would have been present. The cause of the hill diarrhœa was certainly, in many stations, unwholesome drinking-water (see page 40); whether this was the case in all, I am not sure. Some of the hill stations are said not to be adapted for rheumatic cases; in other instances (as at Subathoo) rheumatism is much benefited. I infer, from reading the reports from these stations, that damp barracks, and not the station, have been in some cases the cause of the rheumatism.

But it must be noticed that the evidence given before the Indian Sanitary Commission shows, on all or almost all hill stations, a most lamentable want of the commonest sanitary appliances. At great expense men are sent up to the hills, where everything is, or was, left undone which could make that expense profitable. It appeared to be thought sufficient to ascend 6000 feet to abandon all the most obvious sanitary rules, without which no place can be healthy.

Admitting, as a point now amply proved, that stations of elevation are the proper localities for all troops not detained in the plains by imperative military reasons, the following questions are still not completely answered:—

1. What amount of elevation is the best? We have seen that to reduce the temperature to the English mean, 5000 to 6000 feet must on an average be ascended. But then such an elevation brings with it certain inconveniences, viz., in some stations much rain and even fog at certain times of the year, and cold winds. However unpleasant this may be, it yet seems clear, from the experience of Newera Ellia, in Ceylon, that damp and cold are not hurtful. But it must also be said that, with a proper selection, dry localities can be found at this elevation.

From 3000 to 4000 feet have been recommended, especially to avoid the conditions just mentioned. Whether places of this height are equal in salubrity to the colder and higher points is uncertain.

Even at 6000 feet there may be marsh land, though it is not very malarious. Malarious fever has been known during the rains at Kussowlie (6400 feet), and Subathoo (4000), and other Himalayan stations. Malaria may, however, drift up valleys to a great height,* but, apart from this, it seems likely that 5000 feet, and probably 4000, will perfectly secure from malaria. Probably, indeed, a less height will be found effectual.

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* It has drifted up even to the summits of the Neilgherries, 7000 or 8000 feet.—*Indian Sanitary Report*, Mr Elliot's Evidence, vol. i. p. 250.

At no point do hot land winds occur, or at any rate endure, at above 4000 feet.

On the whole, it would appear probable that the best localities are above 5000 feet, but below 7000.

2. What stations are the best—the tops of solitary hills, spurs of high mountains, or elevated table-lands?

Ranald Martin has called especial attention to the solitary hills, rising as they do sometimes from an almost level plain to 2000 and 3000 feet. Such mountain islands seem especially adapted for troops if there is sufficient space at the top. They are free from ravines conducting cold air from higher land, and are often less rainy than the spurs of loftier hills.

The spurs of the Himalayas, however, present many eligible spots, and so do some table lands. And, perhaps, on the whole, if the elevation is sufficient, it is not a matter of much importance which of these formations is chosen; other circumstances, viz., purity of water, space, ease of access, and supplies, &c., will generally decide.

In choosing hill stations, the points discussed in the chapter on SOILS should be carefully considered, and it is always desirable to have a trial for a year or two before the station is permanently fixed.

In all the presidencies of India elevated spots where troops can be cantoned exist in abundance.* The following table, copied from Dr Macpherson's work, gives some of the principal hill stations. Fresh stations are, however, being constantly discovered, and it seems now certain that there is scarcely any important strategical point without an elevated site near it.

Near Nynee Tal, in Kumaon, are Almorah (5500 feet), and Hawalbagh (4000 feet), both well spoken of. Kunawar (5000 or 6000 feet), in the valley of the Sutlej, has a delicious climate; and Chini (about 100 miles from Simla), is a most desirable spot.

Passing down from the north-west towards Calcutta, Dr M'Clellan found elevated land within 100 miles of Allahabad; and in the south there are the Travancore mountains, with numerous good sites.

If, then, the mass of the troops are cantoned on elevated places, the disadvantages of climate are almost removed. The Indian Sanitary Commissioners recommended that one-third of the force shall be in the hills, and that enfeebled men and recruits especially shall be sent there. But it is to be hoped that not only one-third, but a large majority of the troops will eventually be placed there.

## SUB-SECTION II.—DISEASES OF THE NATIVES.

It is impossible that Europeans can be perfectly isolated from the nations among whom they serve; they have suffered from the pestilential diseases of the Hindus, but still it is wonderful that they have not suffered more. Cholera is the chief disease, which, arising in the native population, scourges their conquerors. Some fevers also, relapsing fever, perhaps a "febris icterodes," or bilious remittent, which has attacked Europeans, have had their

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* See the evidence in the Indian Sanitary Report (vol. i.) of Sir R. Martin, Mr Elliott, Dr Maclean, Dr Alexander Grant, Mr Montgomery Martin, and others. Also most instructive reports by Mr Macpherson, Indian Report, vol. ii. p. 622, and by Dr Alexander Grant, Indian Annals. On the location of troops I may also refer to Surgeon-General Dr Beatson's very decided opinion on the necessity of placing on the hills all the men who can be spared from the military posts in the plains. No more valuable opinion could be given on such a point than that of an officer who has had the largest possible experience, and the best opportunities of forming a correct judgment. (See his Report in the Army Med. Report, vol. viii. p. 347.) Sir William Muir has also urged this point, and the result is that gradually more and more troops are being located on the hills.

| Names of Hill Stations. | | | Mean Temperature outside in Shade. | | | | | | | | | | | | Ascertained greatest Elevation. | Average Fall of Rain in Inches. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | | |
| Bengal Presidency. | Darjeeling, | | 40 | 41 | 51 | 55 | 61 | 62 | 63 | 64 | 63 | 55 | 50 | 44 | 8000 | 132 |
| | Simla, | | 40 | 44 | 53 | 61 | 66 | 80 | 75 | 78 | 70 | 67 | 52 | 46 | 8000 | 70 |
| | Landour, | | 35 | 40 | 51 | ... | ... | ... | ... | 68 | 64 | 49 | 46 | 46 | 7300 | ... |
| | Murree, | | ... | ... | ... | ... | ... | 69 | 68 | 66 | 62 | 62 | ... | ... | 6786 | ... |
| | Kussowlie, | | 42 | 47 | 58 | 64 | 77 | 73 | 70 | 70 | 72 | 66 | ... | ... | 6400 | 70 |
| | Nynee Tal, | | 42 | 46 | 56 | 61 | 69 | 69 | 67 | 69 | 65 | 61 | 50 | 47 | 6200 | 83 |
| | Dugshai, | | 42 | 47 | 57 | 64 | 69 | 71 | 72 | 68 | 66 | 62 | 54 | 53 | 6000 | 70 |
| | Subathoo, | | ... | ... | ... | 77 | 81 | 84 | 79 | 77 | ... | ... | ... | ... | 4000 | 70 |
| Madras Presidency. | Ootacamund, | Neilgherry range. | 54 | 56 | 60 | 61 | 61 | 57 | 63 | 63 | 62 | 56 | 54 | 53 | 7361 | 60 |
| | Kotagherry, | | 59 | 60 | 61 | 63 | 63 | 64 | 65 | 65 | 64 | 62 | 60 | 59 | 6100 | 55 |
| | Wellington, | | 59 | 61 | 67 | 68 | 68 | 64 | 70 | 70 | 70 | 63 | 61 | 60 | 5840 | 50 |
| | Cooneor, | | 60 | 62 | 68 | 68 | 68 | 65 | 70 | 70 | 70 | 65 | 62 | 62 | 5161 | 50 |
| | Pulneys, | | 51 | 53 | 60 | 61 | ... | ... | ... | ... | ... | ... | ... | ... | 7000 | ... |
| | Mercara, | | 53 | 56 | 61 | 64 | 44 | 66 | 65 | 65 | 64 | 65 | 63 | 56 | 4500 | 100 |
| | Annamullays, | | ... | ... | ... | ... | ... | ... | ... | ... | 66 | 56 | ... | ... | 6800 | ... |
| | Shevaroys, | | 65 | 65 | 68 | 71 | 71 | 68 | 68 | 68 | 67 | 66 | 66 | 65 | 5260 | 40 |
| | Ramandroog, | | 70 | 76 | 80 | 80 | 75 | 73 | 71 | 70 | 70 | 71 | 71 | 67 | 3400 | 46 |
| | Cheeuldah, | | 60 | 60 | 70 | 83 | 83 | 71 | .. | ... | ... | ... | 71 | 71 | 3600 | ... |
| | Sindwarrah, | | An average of 8° lower than the station of Kamptee. | | | | | | | | | | | | | |
| | Muthoor, | | Do. 11° do. do. | | | | | | | | | | | | | |
| Bombay Presidency. | Mahableshwur, | | 63 | 65 | 72 | 74 | 72 | 67 | 63 | 64 | 64 | 66 | 64 | 63 | 4700 | 240 |
| | Poorandhur, | | 67 | 73 | 77 | 78 | 73 | 70 | 67 | 65 | 67 | 71 | 69 | 64 | 4200 | 73 |
| | Mount Aboo, | | 61 | 61 | 79 | 77 | 77 | 77 | 69 | 69 | 69 | 69 | 69 | 71 | 4015 | 79 |

origin, or at any rate their conditions of spread, in the dense populations of native cities. Happily, the Black Death (the Maha murree, or Pali plague) has never yet spread to the troops, and has indeed been confined within narrow limits. Still these pestilences among the native population are an ever-present menace to Europeans, and, as in the case of cholera, may pass to them at any time. Cholera, certainly, will never be extirpated until attacked in its strongholds, among the miserable dwellings which make so large a part of every oriental city. In 1867 there were some cases among the troops of the contagious fever, which has caused so much mortality in many of the Bengal jails. The exact influence on Europeans of the customs and modes of life of the natives of India has not, as far as I know, been made an object of special study, but it cannot be inconsiderable. In many places the Europeans and the natives are in close neighbourhood, and the air at all times, and often the water, must be influenced by the social life of the native races. The proximity to large cities or bazaars is indeed often alluded to by army officers as influencing the health of their men; it would be very interesting to know the precise effect. The sanitary condition of almost all the large native towns, and the sanitary habits of the country people, are as bad as can be. Bad water, fœtid air, want of sewage removal, and personal habits of uncleanliness, abound everywhere. The Report of the Indian Sanitary Commission, and the activity of the Indian officials in the Sanitary Departments, are now beginning a series of changes in this respect, which will probably change, *in toto*, the medical history of India.

### SUB-SECTION III.—SPECIAL HYGIENIC CONDITIONS.

The special hygienic conditions (apart from locality) under which the soldier serves in India have been the main causes of excess of disease. This subject has received a searching inquiry from the Sanitary Commissioners.* They declare, and after reading the Station Reports and the evidence given before them, no one will doubt the assertion, that while malaria, extremes of temperature, moisture, and variability of temperature cause a certain amount of sickness, "there are other causes of a very active kind, connected with stations, barracks, hospitals, and the habits of the men, of the same nature as those which are known in colder climates to occasion attacks of those very diseases from which the Indian army suffer so severely."

And the Commissioners enumerate a list of causes connected with unhealthy stations, bad barracks, overcrowding, impure air and water, bad drainage, imperfect ablution, inferior rations and cooking, &c.

In fact no doubt can exist in the minds of all who have studied the subject that these form the most potent class of causes which affect health.

### SUB-SECTION IV.—HABITS AND CUSTOMS OF THE TROOPS.

The habits of the men and the customs of service were, however, also great causes of diseases, and are still so to some extent.

The men were, as a rule, intemperate, great smokers, and indisposed for exertion. It has, indeed, been pointed out with truth, that in proportion to their amount of exercise the men were much overfed, and some diseases of the liver appear to result directly from this simple condition.

The want of exercise is not always the fault of the men. The early morning hours, and often the evening, are occupied with parades; in the period between, the men used to be confined to barracks, and are still sometimes so. Here, listless, unoccupied, and devoured with ennui, they passed the weary day, lying down perhaps for hours daily, or lounging on chairs smoking.

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* Report of the Commissioners on the Sanitary State of the Army in India, 1863. Report, p. 79, published in 1864 in small bulk.

This forced confinement to barracks is indeed an evil often greater than that it is intended to remove. To prevent men from passing out into the sun they are compelled to remain in a hot, often ill-ventilated room, worse for health than the intensest rays of the sun,* that scape-goat of almost every fault and vice of Indian life.

All these causes have been summed up by Miss Nightingale in some of those telling sentences which have done more than anything else to force attention to these vital questions.†

Of late years a great change has taken place in the habits of the men,—more open air exercises of all kinds; and in the cooler stations athletic sports and cricket have been encouraged; in some of the hill stations the troops have been employed in making roads and public works, and the practice of trades has been promoted. Were the troops chiefly on the hills, as much exercise as at home would be possible, and the men would preserve their European vigour and appearance. But even in the plains exercise is necessary, and if it be taken at proper times (*i.e.*, with avoidance of the three or four hottest hours), and with proper precautions, such as keeping the head and spine well covered and cool, putting on after profuse sweating dry and thin mixed cotton and woollen underclothes, and protecting the loins and abdomen with a silk or flannel sash, and avoiding stimulants before and during the exercise, all men would be benefited even by very great exercise.

The pale, feeble appearance of persons who keep much in the darkened houses is really owing more to the absence of light and to the unhealthy and sedentary life than to the effect of the climate.

The subject of clothing has been already referred to. In Algeria, as in India, much good has been ascribed to the use of very large flannel belts, which the French suspend from the shoulders, a plan better adapted for comfort than the so-called cholera belts of India.

With regard especially to diet, two points must be considered:—

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* I shall never forget the sufferings of the men in the old barracks at Madras. We arrived there from Moulmein, where the men had never been confined to barracks, and where, during two hot seasons, no injury had resulted from allowing them to go out when they liked. On arrival at Madras, in accordance with invariable custom, the men were confined to barracks. They lay all day on their beds, reeking with perspiration; the place was so small and ventilation so bad, that the heat was perfectly intolerable in the barracks, though the sun's rays were quite bearable. The sufferings were extreme. When the afternoon came, more injury had been done by the hot and impure air than exposure to the sun's rays could have caused.

At Moulmein, in Tenasserim, at one time, two European regiments served together. The barracks of each were perfectly healthy; the food and duties were the same; yet one showed a sick list and mortality always much greater than the other. Serving in the station shortly afterwards, I was so struck by this difference that I went over all the returns and reports in the staff-surgeon's office to make out the cause; the only difference I could detect was, that in the sickly regiment the men were confined to barracks, in the other they were allowed to go about as they pleased. Many years afterwards, I met with a medical officer who had served in the sickly regiment, and learned from him that he had always considered the confinement to barracks, and the want of exercise, and the impure air breathed by that system almost night and day, to have been the cause of a disparity so striking. No one would recommend imprudent exposure to the sun; men may be trusted to avoid its intensest rays; but to reduce men to enforced idleness for many hours, and to confine them in the small space of a barrack-room is not the way of meeting the evil. (On this point see also page 654 for Dr Clark's observations on want of exercise as compared with exposure to the sun on the West Coast of Africa.) On this point, as in many others, the statements of Dr Kenneth Mackinnon are deserving of great attention. His remarks on the desirability of exercise, even in the trying climate of Tirhoot in Bengal, are very striking. (A Treatise on Public Health, by Kenneth Mackinnon, M.D., Cawnpore, 1848, pp. 27 and 145.) He strongly recommended open sheds and gymnasia, and these are now being adopted.

† How People may Live and not Die in India. By Florence Nightingale, 1863.

1. What amount of food should be taken? In India, as in all parts of the world, food should be taken in proportion to the mechanical work done by the body, and to the equivalent of mechanical force, viz., animal heat.

High temperature, as lessening the loss of the body heat, must, *pro tanto*, lessen the need of food to supply the temperature; and it has been supposed that the diet of men in cold countries (Arctic regions) and in hot, contrasted remarkably in respect of the amount of carboniferous food taken by each. But although it is certain that large quantities of meat and fat are taken by men living in or arriving in cold countries, it is now known that the natives of some of the hottest parts of the world take immense quantities of both fats and starches. In fact, both these substances perhaps, certainly fats, are taken to supply mechanical force directly, as well as animal heat. It is not, in fact, yet known what amount of lessening of food, or what kind of lessening, the increased heat of the tropics demands, or whether any is demanded, for exact experiments are wanting. Our best guide at present for the quantity of food to be taken in the tropics, is to apportion it to the amount of mechanical work done, as in temperate climates. In India, as elsewhere, it must be in balance with exercise. The points then to be considered are the amounts of daily food and of daily exercise, and by means of the tables formerly given, and by knowing the habits of the men, little difficulty will be found in determining the proper ration quantity of food with accuracy.

In considering the amount of food it must be remembered that the soldier almost always buys additional food, and often eats much more than his ration. Some years ago Dr Macnamara found the troops in Bengal taking no less than 76 ounces of food, (*i.e.*, water-containing food), while the regulation ration was only 52 ounces, so that these men were largely over-feeding. And Dr Dempster (Indian Sanitary Report—Evidence) states that the majority of the recruits from Scotland and England eat in the hot weather in India much more animal food than in the coldest seasons in their native countries.*

It would therefore seem that illness may arise in India from excess of food, but it is not the regulation ration which produces it, but the additional purchased food, which is often of bad quality, or the extreme idleness of the men, in which case even the regulation ration is too much. The only remedy is instruction of the men in what is good for them, and no men are so stupid as not to perceive what is best for their own comfort and happiness when it is once pointed out to them.

In addition, the soldier in India had till very lately the spirit ration (now lessened to one-half), which has the effect of lessening the power of appropriation of food, though not always the appetite, and thus indirectly may cause over-feeding.

2. Admitting (till better observations are made) that men in the tropics, undergoing as much exertion as at home, will demand as much food, and in the same proportions, as far as the four classes of aliment are concerned (and it seems to me all physiological evidence shows that this must be the case, and that not external temperature, *per se*, but the work of the body, is the chief measure of food), the next question is, whether the different articles of the diet should be altered; whether, for example, the same amount of nitrogen being given, it should be contained in vegetable or animal food?

It has been stated by several of the best observers in the tropics that those who eat largely of animal food are less healthy than those who take more vegetable food; and Friedel, in his work on China, has lately again directed attention to the fact* that the amount of digestive and hepatic disease is much greater among the English than among any other European settlers in China. But whether this is owing to excessive animal food, or excess generally in all food, and to too much wine, beer, and spirits, is not certain. The diet is probably too rich as a whole.

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* Colonel Sykes long ago directed particular attention to this point, stating with perfect truth, that the soldier in India is over-stimulated by food and drink, and under-stimulated by bodily and mental exercise.

Supposing meat is taken in proper but not excessive quantity with farinaceous food, as at home, is it less healthy than a quantity of vegetable food containing an equivalent amount of nitrogen? On this point it seems to me that strict scientific evidence has not been produced. With regard to excess of animal food there is no doubt; but animal food in moderation has not, I think, been shown to be more active in causing liver complaints in India than at home.

Considering, indeed, how important it is, when the digestive organs have been accustomed to one sort of diet, not to suddenly and completely change it, it seems to me very doubtful whether it would be desirable for the European arriving in India at once to give up all previous habits, and to commence an entirely different kind of diet.

It is possible, however, that the meat standard of England might be somewhat reduced, and the bread, flour, and leguminosæ increased. This is not the opinion, however, of some of those who have lately paid particular attention to Indian rations (Dr C. A. Gordon and Dr Inglis†), and who believe that the amount of meat is even too small.

It has often been said that Europeans in India should imitate the natives in their food, but this opinion is based (it seems to me) on a misconception. The use of ages has accustomed the Hindu to the custom of taking large quantities of rice, with pulses or corn; put an European on this diet, and he could not at first digest it; the very bulk would be too much for him. The Hindu, with this diet, is obliged to take large quantities of condiments (peppers, &c.). The European who did the same would produce acute gastric catarrh and hepatic congestion in a very short time; in fact, as already stated, one great fault of the diet of Europeans arriving in India is too great use of this part of the native diet.

Two points about the diet of India seem quite clear. One is, that spirits are most hurtful, and that even wine and beer must be taken in great moderation. Of the two beverages, light wines (clarets), which are now happily coming into use in India for the officers, are the best. For the men good beer should be provided, but it is important to teach the men moderation. The allowance per man per diem should never be more than a quart, and men would find themselves healthier with a single pint per day. But it would seem probable that, especially in the hot stations and seasons, entire abstinence should be the rule, and that infusions of tea and coffee are the best beverages.‡

The other point is, that in the tropics there is perhaps even a greater tendency to scurvy than at home; the use of fruits, then, is of great importance, and whenever practicable, the growth of fruit trees should be encouraged in the neighbourhood of stations. In some stations (Mooltan) lime juice has been issued with the greatest benefit when vegetables were scarce.

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* Already noticed as regards India and the Mauritius.

† *Op. cit.* and Army Medical Report, vol. v. p. 380.

‡ The drinks which the private soldier often buys in the bazaars in India are of the worst description; arrack mixed with cayenne and other pungent substances, or fermented toddy mixed with peppers and narcotics, or drugged beer, are common drinks. It would be easy to put a stop to this by legislative enactment.

### *Health of the Troops.*

India presents in many respects the same history as our other tropical possessions. In former years there was a large mortality among Europeans, attributed usually to the climate, instead of being put down to its proper causes, viz., a reckless mode of living amidst the most insanitary conditions. As years have passed, the same gradual improvement has occurred in India as in the West Indies. Habits have improved, and the conditions of life have been slowly altered for the better. This change has been going on for years, and there has been an astonishing progress since the mutiny. Much, no doubt, remains to be done, but the fall in mortality and in sickness has been so marked in all the Presidencies, as to lead us to hope that in a few more years the Indian service will, like the West Indian, be almost as healthy as the home service. It may seem rash to anticipate such a result, but an improvement as great has already taken place, for the mortality even now has fallen one-half, compared with that of thirty years ago.

The following table shows this :—

*Earlier Years.—Mortality of Europeans per* 1000 *of Strength.*

| Years and Authority.* | Bengal Presidency. | Bombay Presidency. | Madras Presidency. |
|---|---|---|---|
| 1845–54 (Chevers), . . . . . . | 63·38 | 60·20 | 59·20 |
| 1838–56 (Queen's troops alone—Balfour), . . . . . . . . | 79·20 | 61·10 | 62·90 |
| 1806–56 (Company's troops alone —Indian Sanitary Commissioners), . . . . . . . . . | 74·10 | 66·00 | 63·50 |

In 1812–16, in the Bengal Presidency, the deaths averaged 96·5 per 1000; in the Bombay Presidency in 1819–20 the deaths were 80 per 1000.

The above mean mortality includes every loss; in some years it was, of course, greater, in some less; but on the whole large every year, with a few exceptions, till the year 1856. After the mutiny, about the year 1860, the sanitary improvements and the greater care of the troops which had been gradually taking place received an immense impulse. The results are shown below.

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* The chief statistics of the forces in India are contained in—

1. Numerous scattered papers in the various Indian medical periodicals for the last thirty years, referring chiefly to the health of one presidency or of regiments or forces occupying small districts.

2. Summaries of the whole, by Colonel Sykes (for twenty years ending 1847, Statistical Journal, vol. x.), Sir Ranald Martin (Influence of Tropical Climates, 2d edition); Mr Ewart (Vital Statistics of European and Native Armies, 1859; Drs Waring and Norman Chevers (Indian Annals, 1858–1862); and as far as officers and civilians are concerned, by Colonel Henderson (Asiatic Researches, vol. xx.), and Mr Hugh Macpherson.

3. Official documents, the most important of which are contained in the Indian Sanitary Report; in the yearly Army Medical Department Reports since 1860; in the various Reports of the Sanitary Commissioners in the three Presidencies, in the invaluable Returns of Dr Bryden, and in the Municipal and other Official Reports sent in from towns, or districts. At present the most valuable information is being collected and published in India of the health not only of the European and native armies, but of the civil population; and records of population and of births and deaths are now systematically made. For the first time the Indian Government is gradually obtaining a view of the state of health of the numerous nations it controls.

The Reports from Bengal (Annual Reports of the Sanitary Commissioner with the Government of India) and those from Madras and Bombay are models of their kind, and must have a great effect on the health of the inhabitants of all India. The information given in these excellent Reports is so copious, that it is impossible to give any adequate account of it in this short chapter. I have been able only to note the most striking points.

*Later Years.—Mortality of Europeans per 1000 of Strength.*

| Years and Authorities. | Bengal Presidency. | Madras Presidency. | Bombay Presidency. |
|---|---|---|---|
| | Total Mortality. | Total Mortality. | Total Mortality. |
| 1860–9 (10 years, Balfour), . . | 31·27 | 22·53 | 22·58 |
| 1869–74 (6 ,, ) . . . . . . | 24·45 | 20·62 | 16·61 |
| 1875 (including deaths of invalids) | 18·38 | 15·83 | 21·95 |

*Causes of Sickness and Death.*

The causes of diseases and deaths of Europeans are given in the following table, extracted from the "Army Medical Reports," vol. xvi. The period of five years includes the cholera year 1872, and 1875 was again a year of cholera activity.

*Admissions and Deaths per 1000 of Strength.*

| Causes. | Bengal. | | | | Madras. | | | | Bombay. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1869–74. | | 1875. | | 1869–74. | | 1875. | | 1869–74. | | 1875. | |
| | Adm. | Died. | Adm. | Died. | Adm. | Died. | Adm. | Died. | Adm. | Died. | Adm. | Died. |
| Cholera, . . . | 7·0 | 4·66 | 5·5 | 3·68 | 3·3 | 1·77 | 0·6 | 0·36 | 2·1 | 1·45 | 8·0 | 5·22 |
| Paroxysmal fevers | 454·1 | 1·72 | 361·7 | 0·71 | 115·6 | 0·47 | 74·7 | 0·18 | 492·6 | 1·20 | 410·0 | 0·87 |
| Continued fevers, | 178·3 | 1·99 | 131·3 | 1·96 | 118·0 | 1·54 | 119·1 | 0·80 | 156·0 | 1·76 | 108·5 | 2·18 |
| Eruptive fevers (including Dengue), . . | 2·0 | 0·23 | 2·2 | 0·03 | 1·3 | 0·11 | 1.4 | ... | 1·5 | 0·05 | 0·6 | 0·10 |
| Rheumatism, . | 52·0 | 0·02 | 58·2 | ... | 42·1 | 0·02 | 30·4 | ... | 41·4 | 0·05 | 43·6 | 0·10 |
| Syphilis, . . . | 88·7 | 0·12 | 91·4 | 0·08 | 98·7 | 0·17 | 108·2 | 0·53 | 87·1 | 0·12 | 70·9 | 0·10 |
| Phthisis, Scrofula, &c., . | 10·8 | 1·87 | 8·3 | 1·87 | 13·0 | 1·62 | 10·8 | 1·69 | 10·0 | 1·67 | 7·2 | 1·98 |
| Respiratory, . . | 57·3 | 1·24 | 60·6 | 1·09 | 44·7 | 0·56 | 36·7 | 0·53 | 42·3 | 0·67 | 46·5 | 0·97 |
| Circulatory, . . | 19·6 | 1·65 | 22·7 | 0·98 | 18·7 | 1·99 | 20·9 | 2·05 | 12·5 | 1·19 | 17·1 | 0·96 |
| Nervous, . . . | 20·1 | 2·35 | 21·1 | 2·46 | 20·8 | 2·09 | 13·3 | 1·07 | 16·8 | 2·28 | 17·8 | 3·19 |
| Eye, . . . . | 24·0 | ... | 20·3 | ... | 20·7 | ... | 14·0 | ... | 26·2 | ... | 25·9 | ... |
| Digestive, . . | 250·5 | 5·82 | 222·6 | 3·15 | 348·3 | 7·47 | 294·8 | 5·34 | 217·6 | 3·79 | 242·9 | 3·87 |
| Urinary, . . . | 103·2 | 0·35 | 104·3 | 0·32 | 78·9 | 0·18 | 89·7 | 0·09 | 84·1 | 0·23 | 84·3 | 0·19 |
| Injuries and poisons, . | 90·7 | 1·83 | 94·2 | 1·59 | 115·5 | 2·17 | 95·8 | 2·75 | 95·3 | 1·84 | 112·7 | 1·65 |
| All other causes, | 155·6 | 0·60 | 149·0 | 0·46 | 211·8 | 0·47 | 163·8 | 2·44 | 164·4 | 0·31 | 180·3 | 0·67 |
| Total, . . | 1513·9 | 24·45 | 1353·4 | 18·38 | 1251·4 | 20·63 | 1074·2 | 15·83 | 1449·9 | 16·61 | 1371·8 | 21·95 |

*Analysis of the Statistics.*

The following table shows the distribution of mortality according to age :—

*Deaths per 1000 of Strength at the ages named.*

| All India (Balfour's numbers). | Under 20 years. | 20 and under 25. | 25 and under 30. | 30 and under 35. | 35 and under 40. | 40 and upwards. |
|---|---|---|---|---|---|---|
| 1860–9 (10 years), . . | 9·25 | 17·59 | 24·68 | 34·17 | 44·18 | 60·88 |
| 1870, . . . . | 8·09 | 17·15 | 19·54 | 30·58 | 44·71 | 68·96 |
| 1875, . . . . | 8·42 | 14·40 | 14·30 | 16·90 | 28·74 | 58·01 |
| Presidencies. | | | | | | |
| Bengal 1865–70 (Bryden), | 7·61 | 13·67 | 17·41 | 29·94 | 29·94 | 29·94 |
| Madras 1868–70 (Cornish), | 7·40 | 13·70 | 21·60 | 26·90 | 41·10 | 46·00 |

If these numbers are compared with those of men serving at home (page 608), it will be seen that the mortality at every period is greater in India. If the average for the corresponding years in England be multiplied by three, we have the following table, which comes close to the average Indian numbers:—

*Deaths per* 1000 *of Strength on Home Service multiplied by three* (1859–69).

| Under 20. | 20–24. | 25–29. | 30–34. | 35–39. | 40 and over. |
|---|---|---|---|---|---|
| 8·43 | 17·18 | 22·83 | 36·99 | 46·62 | 55·14 |

This table shows also that the proportion (as between England and India) is preserved throughout, *i.e.*, that the mortality is nearly threefold greater at every age in India.

This regularity of increase is an argument against the view that age, *per se*, increases the total mortality faster than it does at home; and the statistics of officers confirm the inference drawn from the argument. The mortality of the members of the Military and Medical Funds in Madras and Bengal has been carefully determined by actuaries, and the following table proves that mortality among officers does not increase with age in anything like the proportion it does among non-commissioned officers and privates. The large mortality in the earlier ages is owing to the statistics running back to long periods, when the deaths were more numerous.

*Mortality in Officers* (*in Service Fund*) *according to age* per* 1000 *of respective ages.*

| | Under 20. | 20–25. | 25–30. | 30–35. | 35–40. | 40–45. |
|---|---|---|---|---|---|---|
| Madras Military Fund, 1808–1857, . . | 29 | 32·6 | 31·6 | 32 | 29·4 | 28·4 |
| Bengal Military Fund, . | 12 | 22·3 | 24·5 | 27·5 | 29 | 28·9 |
| Madras Medical Fund, 1807–1866, . . | ... | 14·2 | 35·1 | 34·1 | 33·4 | 34·1 |

The mortality among officers of 30 to 35 years of age is, therefore, nearly the same as among privates, but at 35 to 45 it is very much less. Mere climatic conditions, acting more and more as age advances, can therefore not account for the greater mortality of the private soldier, for they would act equally on the officer. No doubt the officer has a more frequent furlough to England; but would this be capable of giving him such an advantage? I think we must conclude that other conditions apart from, or at any rate superadded to, climate, must give rise to the large mortality of the private soldiers.

*Mortality according to Service.*

The question can be further considered by taking into account the effect of service. The following table from Dr Bryden shows the effect of service for three years at the different ages:—

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* Copied from the Report for 1871 of the Sanitary Commissioner (Dr Cornish) for Madras, 1872, p. 7.

*Death-rate per* 1000 *in the European Army of Bengal, excluding Cholera.*

| | Under 20 years of age. | 20-24. | 25-29. | 30 and over. |
|---|---|---|---|---|
| Whole army of 1865-70, . | 7·61 | 13·67 | 17·41 | 29·94 |
| First year of service, . . | 12·93 | 24·87 | 39·32 | 47·08 |
| Second year of service, . . | 3·95 | 15·84 | 23·08 | 35·61 |
| Third year of service, . . | 2·87 | 9·92 | 17·64 | 27·77 |

*Causes of Death per* 1000 *of Strength at different Ages and Service in the Bengal European Army.**

| Causes. | Years. | Ages. | | | |
|---|---|---|---|---|---|
| | | Under 20. | 20-24. | 25-29. | 30 and over. |
| Cholera, . . | Army of 1865-70, | 4·95 | 5·63 | 5·58 | 6·92 |
| | 1st year of service,† | 9·58 | 15·89 | 16·78 | 20·47 |
| | 2d year ,, | ·66 | 2·16 | 4·44 | 4·90 |
| | 3d year ,, | ... | ·17 | 2·62 | 4·91 |
| Fever, . . . | 1865-70, | 4·48 | 4·78 | 2·66 | 2·98 |
| | 1st year of service, | 6·70 | 10·36 | 8·52 | 3·75 |
| | 2d year ,, | 1·97 | 5·76 | 5·77 | 4·75 |
| | 3d year ,, | ·96 | 3·08 | 3·48 | 3·75 |
| Heat apoplexy, . | 1865-70, | ·94 | 1·23 | 2·33 | 4·41 |
| | 1st year of service, | 2·40 | 3·80 | 10·02 | 17·40 |
| | 2d year ,, | ... | 1·08 | 2·66 | 3·60 |
| | 3d year ,, | ... | ·17 | ·87 | 1·45 |
| Delirium tremens, | 1865-70, | ... | ... | ·24 | 1·08 |
| | 1st year of service, | ... | ... | ·75 | 1·71 |
| | 2d year ,, | ... | ... | ·67 | ·98 |
| | 3d year ,, | ... | ... | ·22 | ·87 |
| Dysentery and Diarrhœa, . | 1865-70, | ·57 | 1·82 | 2·81 | 3·20 |
| | 1st year of service, | 1·44 | 3·28 | 5·51 | 5·46 |
| | 2d year ,, | 1·32 | 1·26 | 2·66 | 4·57 |
| | 3d year ,, | ... | ·51 | 1·53 | 4·34 |
| Hepatitis, . . | 1865-70, | ·09 | 1·73 | 3·04 | 5·45 |
| | 1st year of service, | ... | 1·90 | 4·75 | 6·82 |
| | 2d year ,, | ... | 1·44 | 4·22 | 6·86 |
| | 3d year ,, | ... | 1·37 | 3·48 | 5·49 |
| Phthisis, . . | 1865-70, | ·29 | 1·18 | 1·47 | 2·14 |
| | 1st year of service, | ... | 2·59 | 3·76 | 2·39 |
| | 2d year ,, | ... | 2·52 | 2·22 | 2·29 |
| | 3d year ,, | ... | 2·22 | 2·18 | 2·08 |
| Heart disease, . | 1865-70, | ·19 | ·18 | ·92 | 2·88 |
| | 1st year of service, | ·48 | ... | 1·75 | 1·02 |
| | 2d year ,, | ... | ·36 | ·44 | 4·57 |
| | 3d year ,, | ... | ... | ·87 | 2·90 |
| All other causes, . | 1865-70, | 1·05 | 2·75 | 4·44 | 7·80 |
| | 1st year of service, | 1·91 | 2·94 | 4·26 | 8·53 |
| | 2d year ,, | ·66 | 3·42 | 4·44 | 8·17 |
| | 3d year ,, | 1·91 | 2·57 | 5·01 | 6·94 |

The first table in this page brings out very forcibly the great mortality of the first year of service at all ages; the older men suffer as much as the younger; the mortality falls during the second year of service, and in the third is below the mean mortality of the army at large. To determine how far this is owing to climate, we must analyse the causes of this mortality.

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* Appendix C in Bengal Sanitary Report for 1870, p. 255. *et seq.*, and for 1871, p. 212.

† Too much weight must not be laid on these large numbers, as that particular year must have been one of great epidemic prevalence of cholera.

The careful statistics of Dr Bryden enable us to answer this point with some accuracy.*

Certain broad facts are at once shown by the second table on page 677. Leaving cholera out of the question,† the mortality from fevers is seen to be excessive in the first year of service, and to be far greater among the young men; in fact, in men over thirty it is trifling. These fatal fevers are largely made up of typhoid fever,‡ which is known to affect young persons in a far higher ratio than older persons. Heat apoplexy, by which is meant all the forms of "thermic fever," is also extremely fatal in the first year, but its incidence is not on the young but on the old men; on first arriving in India, men over thirty die seven times more from heat diseases than the men under twenty. Two causes may be here acting,—the organs of the older men may not be able to accommodate themselves so easily to the unaccustomed heat as those of young men (see page 441), or the organs (lungs, heart, and brain) of the older men may have been injured by the drinking so common in the army. Probably both causes are in action. Delirium tremens kills no man under twenty, and very few under twenty-five; its effect is most marked after thirty, and the table seems to show that the older drunkards die twice as fast during the first year in India as in succeeding years, as if the hot climate had an unfavourable influence, or they may drink more on first arriving. Dysentery is fatal during the first year, and especially in men over twenty-five; it is less so in the second and third years, but is still higher than the average of the whole army. Its incidence appears to be, then, in the early years of service, and it is more prevalent or more fatal in the older men. Hepatitis kills scarcely any under twenty years of age; its fatality increases as age advances, until at thirty and over it is fifty times as fatal as under twenty; the effect of service upon it is less marked than in the case of the other diseases. Its fatality is no doubt connected with advancing degeneration of the hepatic tissue, produced either by climate, or what is more likely, perhaps, by bad dietetic habits.

When a regiment goes to India the diseases (excluding cholera) to be guarded against during the first two or three years are, for the young men, fevers (in part enteric), and dysentery; for the old men, dysentery, heat diseases, and hepatitis. As a regiment continues to serve in India health improves, until in the third year the mortality is (except in fever and dysentery) lower than the average of the army on a term of years. We do not yet know how long this lessened death rate continues, but eventually the mortality from heat apoplexy and hepatitis again increases, while dysentery and fever both decline.

No doubt the inquiry will eventually lead to still more important results, but even now sanitary measures of value are pointed out. Enteric fever and dysentery have to be prevented among the young men, and there is no reason to doubt that the success which attends preventive measures at home will equally reward similar efforts in India. These two diseases are greatly under the control of sanitary regulations, and their continuance is a slur upon the application of our sanitary knowledge. We may confidently anticipate a decline in their prevalence and mortality.

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* Dr Bryden's statistics, as given in the Reports of the Sanitary Commissioner with the Government of India, and in the separate Blue-Book (Vital Statistics of the Bengal Presidency, 1870) are so much more complete than any other, that they have rendered obsolete all the older records. Dr Cornish's Statistics as contained in the Madras Sanitary Reports are also most valuable.

† The statistics of cholera are given farther on.

‡ For evidence of this see Bryden's Report, and several papers in the Indian Medical Gazette by different officers.

Thermic diseases and hepatitis among the older men first going to India can also be lessened. The diseases arising from heat (either on organs insusceptible of accommodation or commencing to degenerate) must be met by not subjecting men to the influence of heat. The inestimable boon of placing on the hills all regiments which arrive from England will surely not be much longer delayed. These statistics of Bryden prove its necessity, and it is happily a measure which accomplishes many other objects. Malaria is avoided, the chances of cholera are lessened, and the risk of typhoid fever probably diminished. No other plan can be devised which can accomplish so much in the way of prevention, or can aid so greatly in preserving the vigour and power of the soldier. And then, by descent into the plains at certain times, the body will become accommodated to the changed conditions.

It is now an order that no soldier shall go to India until he is twenty years of age. This was not done because a man under twenty suffers more from climate and dies faster; in fact he suffers less and dies more slowly, but he is unfit for the complete work of a soldier until his frame has consolidated. As soon as this has taken place, however, it would appear that he should go to India as early as he can, and, if protected from cholera, enteric fever, and dysentery, he will for some years have as good health as at home. Up to and inclusive of the third year his health will improve with residence; at some subsequent period it deteriorates, but the statistics do not yet show the precise year of service when this occurs. When it is made out, and when it is clear that decided deterioration of health has commenced, the period of service should end, and the soldier should return home.

The means of prevention of enteric fever, dysentery, hepatitis, and cholera have been already noticed (page 488 *et seq.*); but it will be desirable in this place to notice some places connected with the mortality of cholera in Bengal, which appear to point to certain preventive measures.

### *Cholera in the Bengal Preside*

During fifty years (from 1818 to 1867) the mean annual mortality from cholera per 1000 of European strength in Bengal was no less than 9·4. It was the great cause of variation in the percentage of mortality from year to year. The cholera mortality was not owing, as might have been supposed, to service in the stations in Bengal proper (the so-called endemic home of cholera), for the mean mortality in Bengal proper was below that of the Punjab, where cholera is occasional, *i.e.*, prevails only at certain seasons and in certain years. If we compare Bengal proper with two other military districts, Agra with Central India, and the Punjab (as representing Central India and the extreme north-west), two facts come out very clearly—1st. That in Bengal proper the mortality is more steady, but on an average of years is lower than in the other two districts, where the mean mortality is heightened by occasional tremendous outbreaks unknown in cholera's endemic home; 2d. That in Bengal proper the Sepoy mortality is higher than in Europeans, while in the other stations it is much lower.†

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* The statistics referred to in this section are those given by Bryden in his valuable Reports—Vital Statistics of the Bengal Presidency, 1070—and Appendices from Dr Cuningham's Annual Report, but Dr Bryden is not answerable for my way of putting the figures, or for my inferences.

† It has been wrongly stated that the excessive mortality from cholera of Europeans in the Bengal Presidency is an effect of race; the statistics of Bengal proper (as shown in the next table) and of the Madras Presidency entirely disprove this. In the Madras Presidency in 1860–66, the annual European cholera mortality was 3·1 per 1000 of strength, and the Sepoy mortality was 3·07, or virtually the same.

*Table to show the Mortality from Cholera per* 1000 *of Strength in Europeans and Sepoys.*

| Year. | Bengal Proper. | | Agra and Central India. | | Punjab. | |
|---|---|---|---|---|---|---|
| | Europeans. | Sepoys. | European. | Sepoys. | European. | Sepoys. |
| 1861, . . . . . | 6·51 | 6·38 | 41·21 | ·25 | 36·10 | 6·88 |
| 1862, . . . . . | 6·11 | 5·44 | 26·90 | 1·3 | 12·74 | 3·99 |
| 1863, . . . . . | 3·17 | 4·25 | 3·82 | ·4 | ·13 | ·90 |
| 1864, . . . . . | 2·50 | 6·40 | 0·62 | ·0 | ·06 | ·09 |
| 1865, . . . . . | 6·40 | 9·20 | 7·20 | 3·1 | ·14 | 0 |
| 1866, . . . . . | 1·90 | 7·03 | 0·28 | 0 | 0 | 0 |
| 1867, . . . . . | 2·50 | 3·50 | 3·30 | ·9 | 20·7 | 3·9 |
| 1868, . . . . . | 5·34 | 2·51 | 3·36 | ·16 | 0 | 0 |
| 1869, . . . . . | ·53 | 4·43 | 30·18 | 7·25 | 16·86 | 7·33 |
| 1870, . . . . . | 1·00 | 3·03 | ·47 | 0 | 0 | 0 |
| 1871, . . . . . | ·51 | 1·25 | ·24 | 0 | 0 | ·07 |

Although the numbers will not be quite correct, still as the strength of the Europeans and Sepoys did not vary much from year to year, the mean of the whole eleven years may without sensible error be taken from the above averages—

| | Europeans. | Sepoys. | Europeans. | Sepoys. | Europeans. | Sepoys. |
|---|---|---|---|---|---|---|
| Mean of 11 years, . | 3·32 | 4·32 | 10·68 | 1·22 | 7·78 | 2·02 |

The above table is most instructive, and proves beyond doubt that while cholera is never absent from Europeans in Bengal proper* (the endemic home), it never attains the destructive prevalence which occurs in Central India and the Punjab, where it is sometimes entirely absent for years, and yet the severity of the outbreak, when it does occur, makes the mean Punjab and Central India cholera mortality of eleven years far greater than the cholera mortality of Bengal proper.

Among Sepoys the mortality in Bengal proper is actually greater than in Europeans, while it is far less in the Upper Provinces, and in some outbreaks (as in Central India in 1861) the Europeans have suffered frightfully, while the Sepoys have been scarcely touched.

What, then, is the cause that while in Bengal proper, where the conditions of cholera always exist, the mortality should be comparatively low, there should be such terrible outbreaks in up-country stations where cholera is only a visitor, and why should these outbreaks affect the Europeans so particularly? To answer this question we may select a few of the worst stations in Upper India, and see what the mortality was in the great epidemics of 1861–2–7–9.

*Mortality per* 1000 *of European Strength in different Epidemics.*

| | 1861. | 1862. | 1867. | 1869. |
|---|---|---|---|---|
| Meerut, . . . . . | 34·32 | 15·70 | 70·30 | 7·04 |
| Mean Meer, . . . . | 245·63 | 49·93 | 50·49 | 0 |
| Peshawur, . . . . | 0 | 49·24 | 92·93 | 120·14 |
| Agra, . . . . . | 56·56 | 42·5 | 0 | 0 |
| Morar, . . . . . | 137·43 | 37·25 | 11·52 | 82·89 |

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* Since 1871 the ratio of deaths from cholera among European troops has been very small in the Presidency division (including Bengal proper):—

| | |
|---|---|
| 1872, . . . . . . . . . | 0·69 per 1000. |
| 1873, . . . . . . . . . | 0·36 ,, |
| 1874, . . . . . . . . . | 0·25 ,, |
| 1875, . . . . . . . . . | nil. |

This table shows that the outbreaks are very variable in intensity; a station may be quite free from cholera in one epidemic and suffer frightfully in another. In Agra in 1861 there was a tremendous outbreak; in 1867 there was no case, though the disease was all round.

If we now analyse the station statistics themselves, the remarkable fact comes out that some of the severest outbreaks involved only a portion of the Europeans.

| | | | | | |
|---|---|---|---|---|---|
| Thus, at Meerut, in 1867— | | | | | |
| The 19th Hussars were | 430 | strong,* | and lost | 1 | man from cholera. |
| 5 batteries of artillery were | 610 | ,, | | 5 | ,, |
| The first bat. 3rd Buffs were | 679 | ,, | | 105 | ,, |
| The Sepoys had no death from cholera. | | | | | |
| At Mean Meer, in 1867— | | | | | |
| The Royal Artillery | 470 | strong, | lost | 4 | men. |
| The 106th Regiment | 772 | ,, | ,, | 47 | ,, |
| At Umballa, in 1867— | | | | | |
| The 21st Hussars, | 418 | strong, | lost | 2 | men. |
| The 94th Regiment, | 638 | ,, | ,, | 18 | ,, |
| A battery of R.H.A., | 144 | ,, | ,, | | None. |
| A battery of R.H.A., | 133 | ,, | ,, | 1 | man. |
| The Sepoys, | 937 | ,, | ,, | 3 | ,, |
| At Lucknow, in 1869— | | | | | |
| Battery R.H.A., | 131 | ,, | ,, | | None. |
| The 5th Lancers, | 479 | ,, | ,, | 4 | men. |
| 102nd Regiment, | 685 | ,, | ,, | 11 | ,, |
| 62nd Regiment, | 834 | ,, | ,, | 43 | ,, |
| The Sepoys, | 1767 | ,, | ,, | 3 | ,, |

These facts show that the hypothesis of an epidemic influence produced by something floating in the air is incredible, and for such a partial distribution as is shown above would be impossible. If these figures prove anything, it is that the causes of the tremendous loss in these stations is not a generally diffused cause, but a well-marked local development, having narrow limits, and sometimes involving only a single barrack.

At Meerut, in 1867, while the 3rd Buffs were literally more than decimated, the Hussars and Sepoys were as healthy as if they had been in England.

The figures also show that the supposition that the difference in mortality between the Europeans and Sepoys is owing to difference of social habits (especially as regards latrine arrangements) is unlikely, for different bodies of Europeans in the same station suffer as diversely as Europeans and Sepoys.

The localising conditions, which give the intense spread to what is, no doubt, an imported agent, must be referable to either soil, water, air, or food. Faulty latrine arrangements, if they exist, must act through one or other of these media, poisoning the ground, or air, or water. The inquiry into the local spread of cholera, if concentrated on the locality, and carried to the exhaustion of every possible factor, must surely solve this problem. *It is as in* typhoid fever at home, where everything often seems a mystery until a minute search is made, and then what seemed inexplicable is found to be simple.

But, without waiting for the solution of the cause of these localisations of cholera, the fact of the localisation points out preventive measures which, as a matter of reasonable precaution, ought to be taken in every barrack in Upper India where these great outbreaks have occurred. These measures should be adopted on the ground of removing every possible local cause, even though the particular precaution may not have been *proved* to be necessary.

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* The strength is the average strength of the year, and is merely given to show the general [illegible]

1. The influence of the ground should be excluded by the most thorough paving and cementing everywhere, and by careful examination and cleansing under every floor.

2. A fresh water supply should be obtained at any cost, be from an undoubted source, and be kept solely for the use of the barrack.*

3. The cooking arrangements should be entirely remodelled, and the supply of every article of food carefully considered.

4. The latrine arrangements should be remodelled, the places changed, and the system at every point scrutinised to see if soil, air, or water can in any way be contaminated by percolation or emanation.

If, after adopting these measures, and carrying them out fairly in their integrity, an outbreak still occurs, this cannot throw doubt on the correctness of the view which attaches so much weight to localisation; it will only show that we have not solved the problem of the localising agency, and if no other local sanitary measures can be adopted it seems to me that the barrack should altogether be abandoned. But I believe this will not be found to be necessary.†

With regard to Mean Meer, which has suffered so severely and so often from cholera, it is a very important fact that enteric fever has from time to time prevailed at that station, as in 1860–69–70. In the two latter years a careful examination of the water supply was made by Surgeon-Major Skeen, of the 85th regiment, who has kindly given me the evidence on the point. Although his view has been disputed, the facts he mentions in his letter to me have convinced me that in both these years the water was the medium of introduction. The fact, as I believe it, of typhoid fever being thus introduced by well water (temporarily used in the absence of canal water), the chemical analysis showing fæcal impregnation of this well water, and the existence of sources of fæcal contamination of water, all seem to me strongly to indicate that cholera evacuations would also, in all probability, pass into the water, and might account for the fearful outbreaks at Mean Meer. At any rate there can be no doubt that means should be taken to entirely close the wells, which are occasionally used, and if the canal water which is ordinarily used does not give a sufficient supply at all times of the year, that a fresh source should be brought down at any cost. The strong facts given by Dr De Renzy respecting Peshawur prove that the same course should be adopted in that station. These measures are imperatively demanded as a matter of precaution, and no theoretical arguments that the water is not to blame ought to be allowed to override them.

## *Phthisis in India.*

The amount of Phthisis in India is a highly interesting question, and in the following table I have calculated the admissions, deaths, and invaliding from this cause for two successive periods of four years each; the admissions and deaths are also added for the six years ending 1876.

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* Should there be insuperable difficulty attending this, much good might be done by supplying the barracks with distilled water. Even boiling the water before issue would probably be efficacious.—F. DE C.

† For the measures to be adopted during the epidemic, see page [illegible].

*Phthisis, including Hæmoptysis per 1000 of Strength.*

| | Admissions. | Deaths. | Invalided. | Total Deaths & Invalided. |
|---|---|---|---|---|
| BENGAL. | | | | |
| 4 years—(1863–66), . . . | 7·500 | 1·707 | 2·729 | 4·436 |
| 4 years—(1867–70), . . . | 10·080 | 1·752 | 3·636 | 5·388 |
| 6 years—(1869–74), . . . | 10·089 | 1·870 | ... | ... |
| BOMBAY. | | | | |
| 4 years—(1863–66), . . . | 7·756 | 1·526 | 3·280 | 4·806 |
| 4 years—(1867–70), . . . | 9·186 | 1.238 | 3·576 | 4·814 |
| 6 years—(1869–74), . . . | 10·000 | 1·670 | ... | ... |
| MADRAS. | | | | |
| 4 years—(1863–66), . . . | 11·526 | 1·458 | 3·656 | 5·114 |
| 4 years—(1867–70), . . . | 11·950 | 1·336 | 4·737 | 6·073 |
| 6 years—(1869–74), . . . | 13·000 | 1·620 | ... | ... |

How regularly the causes of phthisis must be acting, is seen in the fact that in four years, 1863–66, 74 men died from phthisis in the Bombay Presidency, and 73 in the Madras Presidency, the mean number of troops being in each case almost precisely the same (12,119 and 12,512). In the next four years, with a smaller number of troops, 53 and 55 died in the two Presidencies. In the Bengal Presidency the deaths are higher, but the invaliding is less, so that the slight difference is compensated. More men died, and fewer were sent away.

The table seems to me to show clearly that the immense range and variation of climates in which the troops serve in India, produce no effect whatever on the production of phthisis; and this inference is again strengthened by the fact that the mortality in Bengal from phthisis is almost precisely the same as in Canada (1·707 and 1·71 per 1000).

If the Indian mortality and invaliding are compared with the table already given of phthisis in the home army (p. 609), it will be seen that there is decidedly less phthisis in India. The mortality is less, and the invaliding is far below. There can be no doubt, then, that the causes of phthisis are less active in India than at home; and if these causes are not climatic, must the difference not be found in the larger breathing space and greater lateral separation men have in India?

It would be interesting to have some certain statistics of the amount of phthisis in former years, when men were more crowded; Ewart* gives the deaths in the Bengal Presidency, from 1812 to 1831, as 2·6 per 1000 of strength, and from 1832 to 1851–52, as 1·8 per 1000. In the Bombay Presidency, from 1803 to 1827, they were 1·6, and from 1828 to 1852, 1·4 per 1000. Ewart thinks this indicates a large decrease, but doubts whether this may not be owing to more accurate diagnosis. The table just given shows, however, that in Bombay at any rate the deaths in the years 1863–66 were as great as in 1828–52. In the early period, however, there may have been less invaliding. In the absence of reliable statistics, the question of the relative amount of phthisis now and formerly seems to me impossible to be answered.

With respect to the cure and prevention of phthisis, it seems a great pity to send phthisical invalids to England, where they die at Netley, or are cast out to die miserably among the civil population, when in the Himalayas there are elevated localities which must be particularly adapted for the successful treatment of consumption. When means of communication are improved, it is possible that we may see phthisical invalids going from Europe to the high peaks of the Himalayas, and why should not the European soldier, who is actually in India, benefit by the mountain ranges? A phthisical sanitarium, at an altitude of 10,000 feet, would be likely to cure the disease in many cases, if it were diagnosed early, and then if the men were afterwards kept on the lower hill stations, they would probably become perfectly strong. To send these men home to England, is condemning them to almost certain death. Formerly the distance in India would have been fatal to such a plan, but now, by proper arrangements, even weakly men could be brought from all parts of India. Dr Hermann Weber, who has paid great attention to the effect of altitude on phthisis, holds very decided views as to the beneficial effect of such an arrangement, and has already urged this point on the attention of the authorities.

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* Vital Statistics of the Armies in India, 1859, p. 164.

The other diseases of the lungs are not unknown in India. Pneumonia gives a mortality in Bengal of about ·5 per 1000 of strength, or a little less than at home (= ·571); while in the other two presidencies it is not half this amount. Acute bronchitis also causes in all the presidencies a mortality almost precisely the same as at home (·27 and ·285 per 1000).

### *Loss of Service—European Troops.*

The admissions and mean daily sick have been already given.

As compared with home service, a larger number of admissions, a greater daily number of sick, and a shorter duration of cases, and a larger mortality, indicate not only more sickness, but the presence of very rapid mortal diseases, which shorten the mean duration of all cases.

The chief causes of admissions are "paroxysmal and continued fevers," venereal disease, dysentery, rheumatism, integumentary diseases, and digestive affections (not hepatitis). Hepatitis and cholera cause few admissions, but a large mortality.

With regard to the prevention of those several diseases, enough has been said on the chapter on the PREVENTION OF DISEASE. There is no doubt that much may be done, and probably the sickness and mortality will be reduced, if hill stations are used to the same ratio as in the West Indies.

It is most satisfactory to find that the sickness and mortality are both rapidly falling, owing to the energetic means now being adopted by the Government, and to the increased sanitary powers and improved curative means of the medical officers.

The prevalence of venereal disease demands as much attention in India as in England, but the preventive measures will be much easier. Police regulations and proper surveillance are now being enforced, and Lock hospitals are established in many places. At present twelve men per company are allowed to marry, and it has been supposed by military officers that 25 per cent. could be so allowed. This is much to be desired; but if it be done, the Government must face certain results; proper quarters must be provided, and places for disposal of the women in times of service. It is also very desirable for married men not to move regiments too frequently; and if the plan of giving a regiment two years' service in the hills and one on the plains be adopted, it will put the married people to great expense. Probably it will be found that a longer hill service can be given without injury.*

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* The new short service system will probably change the aspect of the question.

### *Invaliding of European Troops.*

During the last few years the invaliding statistics of Bengal have been given with great care by Dr Bryden.* The invaliding ratio, from all causes, in the Bengal European army, has varied in ten years (1861–70) from 28·09 to 53·98 per 1000 of strength.

In the Bengal army the ratios were per 1000 strength—

| Years. | Under 24.† | 25 to 30. | 30 and upwards. |
|---|---|---|---|
| 1865–70, . . . | 26·55 | 39·74 | 78·34 |
| 1871, . . . . | 25·95 | 40·42 | 68.14 |

The invaliding is high during the early years of service; in 1871, out of 2357 invalids whose residence in India was known, 1202, or 51 per cent., had been only from one to three years in India.

The chief causes of invaliding are phthisis, heart affections, hepatitis, and general debility, and the following table, from Bryden, shows the ratio of these classes :—

| Chief Causes for Invaliding. | 1 to 3 Years. | 6 to 10 Years. | Above 10 Years. |
|---|---|---|---|
| Phthisis, . . . . | 10 | 7 | 4 |
| Heart Affections, . . | 15 | 6 | 8 |
| Hepatitis, . . . . | 17 | 15 | 16 |
| General Debility, . . | 15 | 19 | 28 |
| Per cent. of Total Invaliding, | 57 | 47 | 56 |

The total invaliding is made up of those sent home for discharge and for change of air. From one-third to nearly one-half of all invalids are in the latter category.

### *Mortality of Native Troops.*

Colonel Sykes gives the mortality for 1825–44 as 18 per 1000 of strength for all India; and for Bengal, 17·9; Bombay, 12·9; Madras, 20·95.

In Madras, from 1842 to 1858, the average was 18 per 1000 (Macpherson), of which 6 per 1000 each year were deaths from cholera.

Ewart gives the following numbers (p. 36), per 1000 of strength—Bengal (1826–1852), 13·9; Bombay (1803–1854), 15·8; Madras (1827–1852), 17·5.

Taking successive quinquennial periods, there has been a slight progressive decrease in mortality, but this is less marked than in Europeans.

The excess of mortality is chiefly due to cholera, dysentery, and fever.

In Bengal, in the years 1861–67, the annual mortality per 1000 of men present with the regiments was 14·57. In Madras the average mortality in six years, 1860–66, was 12·6.

The following table gives the mortality of native troops per 1000 of strength in the presidencies of Madras and Bombay in 1870–71; and for Bengal in 1870–71 and 1875.

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* Vital Statistics of the Bengal Presidency, 1870; and 7th and 8th Reports of the Sanitary Commissioner (Dr Cuningham) with the Government of India. I must refer to these elaborate reports for the full details.

† In the Army Medical Reports the ratios are now given for each biennial period up to 30 years of age. (See Report for 1875, vol. xvii.)

| | Bengal. | | | Bombay. | | Madras. | |
|---|---|---|---|---|---|---|---|
| | 1870. | 1871. | 1875. | 1870. | 1871. | 1870. | 1871. |
| Cholera, | ·75 | ·84 | 1·69 | ... | ·3 | ·55 | ·32 |
| Small-Pox, | ·13 | ... | 0·20 | ... | ... | ... | ... |
| Intermittent, Remittent, and Continued Fever, | 4·65 | 2·64 | 2·56 | 2·1 | 2·4 | 1·97 | 1·4 |
| Apoplexy and Sunstroke, | ·23 | ·13 | 0·33 | ·1 | ·2 | ·19 | ·2 |
| Dysentery, | 1·94 | 1·09 | 0·92 | ·4 | ·4 | ·27 | ·64 |
| Diarrhœa, | 1·06 | 1·30 | 0·82 | ·4 | ·1 | ·35 | ·84 |
| Hepatitis, | ·13 | ·2 | 0·10 | ·2 | ·2 | ·19 | ·16 |
| Spleen Disease, | ·25 | ·43 | 0·56 | ... | ... | ·03 | ·04 |
| Respiratory Diseases, | 3·22 | 4·19 | 3·17 | 1·8 | 3·1 | 1·23 | ·64 |
| Phthisis, | ·88 | 1·04 | 0·15 | ·4 | ·3 | ·67 | ·84 |
| Heart Disease, | ·20 | ·20 | 0·77 | ... | ·4 | ·47 | ·4 |
| Dropsy, | ·17 | ·05 | 0·03 | ... | ... | ·75 | ·56 |
| Scurvy, | ·17 | ·08 | 0·10 | ·2 | ·4 | ... | ... |
| Atrophy and Anæmia, | ·48 | ·48 | 0·36 | ·1 | ·1 | ·47 | ·18 |
| Wounds and Accidents, | ·20 | ·20 | 0·28 | ... | ·1 | ·11 | ·12 |
| All other Causes, | ·98 | 1·30 | 0·95 | 2·8 | 2·4 | 2·93 | 2·48 |
| Died out of Hospital, | ·45 | ·81 | 0·56 | ... | ... | ... | ... |
| Total, | 15·89 | 15·04 | 13·55 | 8·5 | 10·6 | 9·48 | 8·84 |

## SECTION IX.

## CHINA.

### Hong-Kong.

Although the English have occupied Canton, Tientsin in the north, and several other places, yet, as their occupation has been only temporary, it seems unnecessary to describe any other station than Hong-Kong.

Garrison of Hong-Kong about 1000 to 1500, but differing considerably according to the state of affairs in China.

The island is 27 miles in circumference, 10 long, and 8 broad at its widest part.

*Geology.*—The hills are for the most part of granite and syenite, more or less weathered. In some parts it is disintegrated to a great extent, and clayey beds (laterite) are formed, in which granite boulders may be embedded. Victoria, the chief town, stands on this disintegrated granite. As in all other cases, this weathered and clayey granite is said to be very absorbent of water, and, especially in the wet season, is considered very unhealthy.

*Climate.*—Mean annual temperature, 73° Fahr.; hottest month (July) 86°·25; coldest month (January), 52°·75; amplitude of the yearly fluctuations, 33°·5.

The humidity is considerable, about 10 grains in a cubic foot of air in July, and four in January.

The N.E. monsoon blows from November to April; it is cold, dry, and is usually considered healthy and bracing; but if persons who have suffered from malaria are much exposed to it, it reinduces the paroxysm. The S.W. monsoon blows from May to October; it is hot and damp, and is considered enervating and relaxing. The difference in the thermometer between the two monsoons has been said to be as much as 46°, but this seems excessive.

The rainfall is about 90 inches with the S.W. monsoon.

In addition to Victoria, there are two or three other stations which have been occupied as sanitaria, viz., Stanley, seated on a peninsula on the south end of the island, and about 100 feet above the sea; and Sarivan, 5 miles east of Victoria. Neither station seems to have answered; the barracks are very bad at Stanley, and are exposed too much to the N.E. monsoon, which, at certain times, is cold and wintry; during the S.W. monsoon it is healthy. Sarivan has always been unhealthy, probably from the neighbourhood of rice fields. Since the close of the last war a portion of the mainland, Cowloon, opposite Victoria, has been ceded, and has been occupied by troops. It is said not to be, however, even so healthy as Hong-Kong,* but there are differences of opinion on this point.

Hong-Kong has never, it is said, been considered healthy by the Chinese. The chief causes of unhealthiness appear to be the moist laterite and weathered granite, and the numerous rice fields. Indeed, to the latter cause is ascribed by some (Smart)† the great unhealthiness, especially when the rice fields are drying in October, November, and December.

Local causes of unhealthiness existed till very lately in Victoria. In building the barracks the felspar clay was too much cut into, and, in addition, the access of air was impeded by the proximity of the hills. The S.W. monsoon was entirely shut out. Till lately sewerage was very defective.

Owing probably to these climatic and local causes, for many years after its occupation in 1842, Hong-Kong was excessively unhealthy. Malarious fevers were extremely common, and not only so, but it is now known that typhoid fever has always prevailed there (Becher and Smart). Dysentery has been extremely severe, and has assumed the peculiar form of lientery. This was noticed in the first China war, and appears, more or less, to have continued since. In addition to these diseases, phthisis appears to have been frequent.

There have been of late years such frequent wars in China, that the exact amount of sickness and mortality, due to the climate of Hong-Kong, cannot be well determined. But it is becoming much healthier than in former years, owing to the gradual improvement in sanitary matters which goes on from year to year. In 1865 there was, however, much sickness, owing apparently to overcrowding, and to bad accommodation.

In the Statistical Reports, the troops serving in Hong-Kong, Cowloon, Canton, and Shanghai, are classed together, so that the influence of Hong-Kong *per se* cannot be known.

In the years 1859–66, which include years of war, the admissions in South China averaged 2131, and the deaths 56·25, or, exclusive of violent deaths, 52·63 per 1000 of strength, and there was in addition a large invaliding. Paroxysmal fevers gave 609 admissions and 7·77 deaths; continued fevers, 25·25 admissions and 4·17 deaths; and dysentery and diarrhœa, 249 admissions and 16·3 deaths per 1000. In later years the mortality was less; in 1869–70, it was 16·02, and in 1871 only 5·82 per 1000 of strength, and of these only 3·88 was from disease. In 1875 it was 9·44. It is evident that the causes of sickness and mortality are now being brought under control.‡

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* See Report of Surgeon Snell, Army Medical Report, vol. v. p. 360, for the causes of the unhealthiness of Cowloon.

† Transactions of the Epid. Soc., vol. i. p. 191. This paper should be consulted for an excellent account of Hong Kong, and of the diseases among sailors especially.

‡ *Australia and New Zealand.*—The withdrawal of the troops from these colonies renders it unnecessary to give any statistical details.

# CHAPTER V.

## SERVICE ON BOARD SHIP.*

SERVICE on board ship must be divided into three sections, corresponding to three different kinds of service.

1. Transport ships, for the conveyance of healthy soldiers, their wives and children, from place to place, or for conveying small parties of troops in charge of convicts.

2. Transports for conveyance of sick from an army in the field to an hospital in rear, or from a foreign station to a sanitarium, or home. Although the term is a little odd, it is convenient to call these ships Sick Transports.

3. Hospital ships, intended for the reception and treatment of the sick.

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* Although the conditions of life on board ship are most important, it is not possible for me, with due regard to space, to enter into the subject. But the necessity of thorough study has been well shown by a very valuable essay of Dr Rattray's, read before the Medico-Chirurgical Society in 1872, and from this I extract a few points of great interest. In H.M. frigate, Bristol, used for training of cadets (wooden ship, ventilated chiefly with windsails, the results of 150 analyses of the air between decks, during voyage to the Cape and back (average sleeping cubic space 105 to 222 cubic feet for the crew, and from 242 to 506 for cadets), showed that the impurity was immense; the average $CO_2$ was no less than 16·4 volumes per 1000, with a range of from 4·2 up to 33·71 volumes in the most crowded parts. The reason, no doubt, of this most unusual amount, is not only great crowding, but a constant residuum of impurity, arising from continued occupation and very slow renewal of air. In parts also the products of combustion accumulate. Rattray mentions that lime-wash soon gets discoloured, and effervesces with acid. In the tropics, although the ship was more open, the air was as impure as in colder regions, owing, no doubt, to its greater stagnancy. Sulphuretted hydrogen and sulphide of ammonium, derived from decomposition of the sulphates in bilge-water, &c., from rotten timber, and from decomposing excreta, existed in considerable amount, from ·000578 to ·049049 volumes per 1000 (the latter was in the bilge); it was most where the crowding was greatest. Ammonia was also in large amount; ozone was deficient, and was almost wanting in the lowest parts of the ship; the quantity of substances decomposing potassic permanganate was great, 1 milligramme of permanganate being destroyed by from 5 cubic feet (in the cells) to 12 cubic feet (lower deck). As regards temperature, the air was cooler by night than day, but was warmer by 3° or 4° than the external air. The suspended matters in the air of the ship were large in amount, and consisted of debris of wood, metal, sail, rope, clothing, epithelium, and gritty matter; 3 grains of fine greyish dust from between the beams of the lower deck gave 78·34 per cent. of destructible matter, and 26·66 per cent. of mineral substance. In the air of the lower and main deck, there were minute living acari, legs of insects, and small round and oval bodies, similar to those described by Lemaire and Trautman. Dr Rattray points out the highly deleterious effect of breathing such an atmosphere as this on the great function of respiration and aeration.

The following examination of bilge-water, collected seven days after the bilge had been sluiced, is of interest. The specific gravity (at 74° Fahr.) was 1031, the sea-water being 1027 (temp. 71°); there was a tolerably clear supernatant strongly alkaline fluid, with a fœtid smell, and evolving sulphuretted hydrogen in sufficient amount to darken, in five minutes, paper soaked in acetate of lead solution, and held over it. There was a copious, dark, highly offensive sediment, showing under the microscope small particles of wood, sand, coal, white-wash, &c. It is clear that the sea-water, after passing into the ship, became concentrated, and was acted on by various organic matters.

Seven specimens of bilge-water examined at Netley by Drs Macdonald and de Chaumont from iron, wooden, and composite ships (sea-water with solids varying from 891 to 2885 grains per gallon), at first contained sulphuretted hydrogen, but after four months' exposure in loosely corked bottles, the sulphuretted hydrogen entirely disappeared; there were no alkaline sulphides. This shows that the production of $SH_2$ occurs from changes produced in the bilge-water by the materials of the ship, and does not go on when the bilge is removed from the influence of the ship. It was as great in iron as in wooden ships. There was no nitric acid, and only a trace of nitrous acid in the bilge; the free ammonia was very small in amount, and the albuminoid ammonia varied from ·8 to 1 milligramme per litre. The absence of life was remarkable; there were only a few dead organisms, and these seemed as if attenuated and starved.

## SECTION I.

### TRANSPORTS FOR HEALTHY TROOPS.

The use of Government transports has very much altered the duty of medical officers on board. The transports are really men-of-war, *i.e.*, officered by the Royal Navy, and under naval regulations. The medical officer of troops has therefore nothing to do with the vessel and its arrangements. It seems improbable that hired transports will be much if at all used in future, and therefore it is not necessary to go into the details given in the former editions of this work.

In case there should be any service of the kind, the Queen's Regulations (section xxii., Duties on Board Ship) and the Medical Regulations (part iv. section v.) have to be carried out.

## SECTION II.

### TRANSPORTS FOR SICK TROOPS.

No specific regulations are laid down with respect to these hired ships, but it would be very desirable to have some set rules with respect to space, diet, and fittings. Invalids are now carried from India and the Colonies in Government transports; occasionally hired transports are used. At present the diet of invalids on board the hired transports is not good. In respect of fittings, the use of swinging cots for feeble men, and well-arranged closets for dysenteric cases, are very important. So also with the cooking; the coarse ship cooking is a great trial to many patients. If there is need of Government transports for healthy men, the necessity is still greater for sick men.

As far as possible, the sick should be treated on deck in fine weather, a good awning and a comfortable part of the deck being appropriated to them. I believe that it would be a good plan not to send home officers and sick men in the same ship, but to have officers' ships, so as to give up the poop to the men in the ships which carried them. This division will be a gain to both.

In time of war, sick transports are largely used to carry troops to hospitals in rear. For this purpose good roomy steamers must be chosen. For economy's sake, they will generally be large, and probably with two decks; they should never have more, and indeed a single deck is better. But if with two decks, each space should be separately ventilated by tubes, so as, as far as possible, to prevent passage of foul air from the lower to the upper deck. All the worst cases should be on the upper deck, especially surgical cases.

The decks of these vessels should be as clear as possible, so that men can be treated on deck. An apparatus should be arranged for hoisting men on deck from below.

It has been proposed to fit these ships with iron bedsteads, and no doubt this gives the men more space; but a better plan still would probably be to have short iron rods, to which every cot could be suspended. The sick men might be carried in their cots on board, and again removed. If the rods are made about 14 inches high, and bent in at the top so as to form a hook, a cot is hung easily, and will swing. There is space enough below to put a close-stool or pan under the man without stirring him, if a flap is left open in the canvas, and a hole left in the thin mattress.

Fixed berths are not so good, but some must be provided. Some cots can swing from the top, and some men can be in hammocks. Probably every sick transport should have all these, viz., iron bedsteads at some points fastened to the deck, iron standards for swinging cots, cots swinging from the roof, low berths, and hammocks.

In these sick transports the kits and clothes must be stowed away; and as they are often very dirty and offensive, and sometimes carry the poison of typhus and other diseases, the place where they are put should be constantly fumigated with nitrous and sulphurous acid alternately. Robert Jackson mentions that dirty clothes and bedding may be soon washed sweet by mixing oatmeal with salt water.

Directly a sick transport has landed the sick, the whole place should be thoroughly washed and scraped, then the walls and ceiling should be lime-washed, and the between-decks constantly fumigated till the very moment when fresh sick embark.

## SECTION III.

## HOSPITAL SHIPS.

These are ships intended for the reception and treatment of the sick,—floating hospitals, in short. Whenever operations are undertaken along a seaboard, and especially when a force is moving, and places for fixed hospitals cannot be assigned, they are indispensable. They at once relieve the army from a very heavy encumbrance, and, by the prompt attendance which can be given to the sick, save many lives. They should always be organised at the commencement of a campaign. In the late Abyssinian war three hospital ships were used. Their fitting out was carefully superintended by Deputy-Inspector-General Dr Massy, and appears to have answered admirably. A full account of one of these ships ("Queen of the South") was given by the late Staff-Surgeon Charteris, to which reference may be made. The ventilation, as shown by the amount of carbonic acid (·708 per 1000 volumes) was very good.* The superficial space between decks per man was on the night of the experiment 154 feet, and the cubic space no less than 1076. During the Ashanti war (1873–4) the line of battle ship "Victor Emanuel" was used as an hospital ship, and was most successful. A very full and detailed account of it is given by Surgeon-Major T. M. Bleckley, C.B., in medical charge (see Army Medical Reports, vol. xv. p. 260.) The floor space per head was generally about 50 square feet, and the cubic space about 480, although it was originally intended to be less.

However convenient, and indeed necessary, they are, it must be clearly understood that they are not equal to an hospital on shore. It is impossible to ventilate and clean them thoroughly. The space is small between decks. The wood gets impregnated with effluvia, and even sometimes the bilge is contaminated. I have been informed by Dr Becher, late pathologist in China, that even in the very best of the hospitals used there, it was quite clear that in every wound there was evidence of a slight gangrenous tendency. In fact, it is perhaps impossible to prevent this, except by the most vigorous antiseptic treatment.

The principle of separation should be carried out in these ships—one ship for wounded men, another for fevers, a third for mixed cases; or if this cannot be done, separate decks should be assigned for wounded men and fever cases. In fine weather the sick should be treated on deck under awnings. The between-decks must be thoroughly ventilated, and all measures of fumigation, frequent lime washing, &c., must be constantly employed. Charcoal, also, in substance should be largely used, and is, in fact, quite indispensable. Warming by stoves must be used in damp and cold weather, and, if so, advantage should be taken of this source of heat, and of all lights, to improve ventilation.

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* I have to thank Dr Woodward for allowing me to read his excellent Report on the Hospital ship "Mauritius," which was also employed in Abyssinia.

Ships of one deck are better than two; but as they will hold a very small number of sick, two decks are commonly used. But not more than two decks should be used; and if there be a third or orlop deck, it should be kept for stores. Sometimes, if there are two decks, the upper deck is used for officers and the lower for troops, but the reverse arrangement should be adopted.

The ventilation of the between-decks, in addition to Edmond's plan, should be carried on by tubes, which, if the central shaft is acting, will be all inlets, and can be so arranged as to cause good distribution of the air.

The fittings of an hospital ship should be as few and simple as possible, and invariably of iron. Tables should be small, and on thin iron legs. Swinging cots (as noticed in the former section) are indispensable for wounded men, and the appliances for the receiving and removing the excreta of dysenteric and febrile patients must be carefully attended to. Berths should not be of wood, but of iron bars, which are much more easily laid bare and cleaned.

The supply of distilled drinking water should be as large as possible, and a good distilling apparatus should be on board, whether the vessel be a steamer or not.

The laundry arrangements are most important, and I believe it would be a good plan, on a large expedition, to have a small ship converted entirely into a laundry. It would not only wash for the sick, but for the healthy men also. So also a separate ship for a bakery is an important point, so as to have no baking on board the hospital ship.

On board the hospital ship there should be constant fumigation; limewashing, whenever any part of the hospital can be cleaned for a day or two, and, in fact, every other precaution taken which can be thought of to make the floating hospital equally clean, dry, well aërated and pure, as an hospital on shore.

On board hospital ships it is often easy to arrange for sea-bathing and douching; it should never be forgotten what important curative means these are.

In case pyæmia and erysipelas, or hospital gangrene occur, the cases must be treated on deck, no matter how bad the weather may be. Good awnings to protect from wind and rain can be put up.

If cows or goats are kept on board to supply milk, their stalls must be kept horoughly cleaned. But generally it is better to obtain milk from the shore.

# CHAPTER VI.

# WAR.

THE trade of the soldier is war. For war he is selected, maintained, and taught. As a force at the command of a government, the army is also an agent for maintaining public order; but this is a minor object, and only occasionally called for, when the civil power is incompetent.

In theory, an army should be so trained for war as to be ready to take the field at literally a moment's notice. The various parts composing it should be so organised that, almost as quickly as the telegram flies, they can be brought together at any point, prompt to commence those combined actions by which a body of men are moved, fed, clothed, kept supplied with munitions of war, maintained in health, or cured if sick, and ready to undertake all the engineering, mechanical, and strategical and tactical movements which constitute the art of war.

That an organisation so perfect shall be carried out, it is necessary that all its parts shall be equally efficient; if one fails, the whole machine breaks down. The strength of a chain is the strength of its weakest link, and this may be said with equal truth of an army. Commissariat, transport, medical, and engineering appliances are as essential as the arts of tactics and strategy. It is a narrow and a dangerous view which sees in war merely the movements of the soldier, without recognising the less seen agencies which insure that the soldier shall be armed, fed, clothed, healthy, and vigorous.

During peace the soldier is trained for war. What is meant by training for war? Not merely that the soldier shall be taught to use his weapons with effect, and to act his part in that machine, where something of mechanical accuracy is imprinted on human beings, but that he shall also know how to meet and individually cope with the various conditions of war, which differ so much from those of peace.

It is in the nature of war to reinduce a sort of barbarism. The arts and appliances of peace, which tend, almost without our care, to shelter, and clothe, and feed us, disappear. The man reverts in part to his pristine condition, and often must minister as he best may to his own wants. No doubt the State will aid him in this; but it is impossible to do so as completely as in peace. Often, indeed, an army in war has maintained itself in complete independence of its base of supplies, and in almost every campaign there is more or less of this independence of action.

In peace, the soldier, as far as clothing, feeding, shelter, and cleanliness are concerned, is almost reduced to the condition of a passive agent. Everything is done for him, and all the appliances of science are brought into play to save labour and to lessen cost. Is this the proper plan? Looking to the conditions of war, ought not a soldier to be considered in the light of an emigrant, who may suddenly be called upon to quit the appliances of civilised life, and who must depend on himself and his own powers for the means of comfort, and even subsistence?

There is a general impression that the English soldier, when placed in unaccustomed circumstances, can do nothing for himself, and is helpless. If so, it is not the fault of the man, but of the system, which reduces him to such a state. That it is not the fault of the man is shown by the fact that, however helpless the English soldier may appear to be in the first campaign, he subsequently becomes as clever in providing for himself as any man. The Crimean war did not perhaps last long enough to show this, but the Peninsular war proved it. The soldier there learned to cook, to house himself, to shelter himself from the weather when he had no house, to keep himself clean, and to mend and make his clothes. Was it not the power of doing these things, as well as the mere knowledge of movements and arms, which made the Duke of Wellington say that his army could go anywhere and do anything? And the wars at the Cape and in New Zealand have shown that the present race of soldiers, when removed from the appliances of civilised life, have not lost this power of adaptation.

The English soldier is not helpless; he is simply untrained in these things, and so long as he is untrained, however perfect he may be in drill and manœuvre, he is not fit for war. The campaign itself should not be his tutor; it must be in the mimic campaigns of peace, in which the stern realities of war are imitated, that the soldier must be trained. Our present field-days represent the very acme and culminating point of war,—the few bright moments when the long marches and the wearisome guards are rewarded by the wild excitement of battle; but the more common conditions of the campaign ought also to find their parallel. Since the Crimean war, much has been done to instruct the soldier in the minor arts of war. The establishment of camps has to some extent familiarised him with tent life; the flying columns which go out from Aldershot show him something of the life of the bivouac, and the training in cooking which Lord Herbert ordered is teaching him how to prepare his food. The Autumn Manœuvres have extended this system, and are now making him familiar with the chief conditions of the life in campaigns.

A campaign can never be successful unless the men are healthy. How are men to be trained so as to start in a campaign in a healthy condition, and to be able to bear the manifold trials of war? The answer may be given under three heads—

1. Preparation for war during peace.
2. Entry on war.
3. Actual service in war.

## SECTION I.

## PREPARATION FOR WAR DURING PEACE.

The various conditions of war, which are different from those of peace, are—

1. *Exposure to the Weather.*—It is a constant observation that men who have led out-door lives are far more healthy in war than men whose occupations have kept them in houses. The soldier's life should be, therefore, an out-door one. This can only be done properly by keeping him in tents during the summer. It would be well, in fact, to tent the whole army from the middle of May to the end of September every year. The expense should be looked on as a necessary part of the military establishments. Wooden huts are too like ordinary barracks. As the soldier has often to sleep out in war, he should be accustomed to this also in peace—warm summer nights being first selected to train him. It will soon be found that he will very soon acquire the power of resistance to cold. This plan will also test the utility of

his clothes.[*] It has been found by experiment that, by careful training, even delicate persons can bear sleeping out at night, even in tolerably cold weather, without injury, provided there be no rain. At the latter end of the summer, it would be well to expose the men even to rainy nights, their clothes being adapted for this, by the supply of waterproofs; and in the very useful Autumn Manœuvres this plan might be tried with advantage.

At the same time, it is important to have the men raised off the ground, both when in tent and lying in the open air, in all countries where the ground may be moist, or cools rapidly during the night. A very useful field hammock has been invented by Captain M'Quire; it consists of a strong woollen material, which is suspended on two sticks by means of guide-ropes. It makes a comfortable bed, and keeps the body very warm.

It may be thought that training of this kind is needless, and that it may be left to the campaign to accustom the men to exposure, but this is not the case; a number of men are rendered inefficient at the commencement of a campaign simply by the unaccustomed exposure.

2. *Tent and Camp Life.*[†]—The pitching, striking, and cleansing of tents (see page 558); the digging trenches round the tents, and providing for general surface drainage; the arrangement of the interior of the tent, &c., should all be carefully taught. So also the camp life of the campaign should be closely imitated, and the rules of conservancy most strictly carried out as a means simply of teaching what will be of such importance in war.[‡]

3. *Cooking of Food.*—No doubt, in future wars, all governments will endeavour to supply prepared and cooked food (see page 271), so as to lessen the cost of transport and the labour of the soldier. But as this cannot always be depended upon, the soldier must be trained to cook his ordinary rations. This should not be done for him; he ought to do it himself merely with the appliances he would have in war, viz., his camp-kettle, canteen, and tin plate.

At the commencement of a campaign many men lose flesh and strength, or suffer from diarrhœa, from the food being badly cooked and indigestible.

In the Peninsular War the men became admirable cooks. At first very large camp-kettles, intended for half a company, were used, and were carried on horses. They did not answer, and the men left them behind. Afterwards smaller camp-kettles were supplied, one for each mess of six or eight. Luscombe mentions that the supply of salt was found to be a very important point; he says, he had no idea of the value of this condiment till he saw the way in which the men saved every little particle; without it, in fact, animal and even vegetable food is unsavoury.

In the French army on service 8 or 10 men form a corporal's detachment, or "escouade." They have between them one kettle and cover (*marmite*, weight 1-7 kilog.), one large bowl (*grande gamelle*, weight 1 kilog.), and one large drinking vessel (*grand bidon*, weight 1-5 kilog.) Each man has for his personal use a small bowl (*petite gamelle*), and a small drinking vessel (*petit bidon*). They are all of tinned iron. All these vessels are carried by the men, the larger vessels being taken in turn by the men of the mess.

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[*] In reference to what was said (p. 577) of the great importance of a hood to the greatcoat for men who sleep out at night, an old observation of Donald Monro is of interest. He states that in 1760 the greater health enjoyed by the Austrian Hussars over the other troops was owing to the half-boots, and the large cloaks with hoods carried by these men.—*On the Means of Preserving the Health of the Army* (2d edit. 1780, p. 7).

[†] I may refer here for fuller details to some excellent treatises on Camps published in Germany and Russia, especially by Dr Roth (Das Zeltlager auf der Lockstädter Heide in Holstein, 1866), and by Dr Heyfelder (Das Lager auf der Krasnoe-Selo, [illegible]

[‡] Reference has already been made to the very useful Soldier's Pocket Book, by Sir Garnet Wolseley, which gives full details on all these points.

It may be concluded with regard to this very important matter of cooking utensils, that a man should have a small but very strong canteen, made of unsoldered tin, and with a good deep lid, with a handle which may serve as a frying-pan or second vessel, as well as a cover. The shape of the canteen should be long and flat, and not deeper than is necessary for cooking, so that it may be easily carried. Then all the other vessels, the camp-kettles for each mess, and the large water vessels, should be carried for the men. They should be made of thin steel, which is very light for its strength, very durable, and is not acted on by the food.

The different kinds of camp cooking to be taught are stewing, boiling, and making soup, making tea and coffee, cooking preserved vegetables, making cakes of flour, and oatmeal porridge.

Reference has already been made to the great importance of not keeping men too long without food. By a little arrangement men can always carry food, and the proper organisation of supplies and regimental transport would always enable a commanding-officer to have some food for his men. In almost all marches, with large bodies of men, and in many actions, there are long periods of inaction during which men could eat food which had been already cooked. The effect of this upon their strength, endurance, and even courage, is remarkable. Some instances have been related to me by officers in which failures resulted entirely from the exhaustion of the men produced by want of food. Surely it is useless to supply ammunition for guns if the men who are to work have no supply of force issued also to them.

4. *Water Supply.*—As impure water is a great cause of sickness in war, the soldier should be taught how to recognise impurity, and how to use the simple methods of purification with charcoal, alum, tea, boiling, &c. (See chapter on WATER.)

5. *Mending Clothes.*—Every soldier carries a hold-all, but many cannot use it properly. It may be suggested whether, in the workshops which are now being established, it would not be well to let every recruit have a month's practice in repairing clothes, and especially boots; simple plans of repair being selected if it be possible.

6. *Cleanliness.*—In war a source of disease is the want of cleanliness. Very soon the person and clothes get covered with lice; all the garments, outer as well as under, get impregnated with sweat, and become very filthy. The best generals have always been very careful on this point, and have had frequent washing parades. As washing clothes is really an art, the soldier should be taught to do it, not by machinery, but in the rude fashion he must practise during war. Clothes can be partially cleaned by drying and beating.

The hair should be cut short. In the absence of water for washing, the best plan is the small-tooth comb, to keep the hair free from vermin, and it may be a question whether one should not be supplied to every soldier.

Washing the whole body in cold water, whenever it can be done, is not only bracing and invigorating, but strengthens it against vicissitudes of weather, and against dysentery.*

## SECTION II.

## ENTRY ON WAR.

When actual war commences some further steps become necessary.

All experience shows that men under twenty or tweny-one years of age cannot bear the fatigues of war.[*] If possible, then, all men below twenty-one, or at any rate below twenty, should be held back from the campaign, and formed into depôts, whence they may be draughted for active service on occasion. Of course every means should be taken during their service at the depôts to strengthen and harden them.

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* Both Donald Monro and Lind notice this.

All weakly men should also be held back, and every man thus retained should come under the surgeon's superintendence, not in hospital, but while doing his duty.

The men who are about to enter on the campaign should at once commence a more severe training. If there be time to do it, this should be carried to an extent even greater than will be demanded in war, in the manner of the Romans, who trained their soldiers so severely in peace that war was a relief. Footsoreness is very common at the commencement of a campaign, and often gives great trouble (see page 601).

Certain changes in the food of the men should be made.

The exertions of war, bodily and mental, are often very great, and demand an increased quantity of food, especially in the nitrogenous and fatty elements; an increased amount of meat and bread, with the addition of fat bacon, cheese, and peas or beans, should be given, so as to bring the daily amount of nitrogen to 375 to 400 grains, and of carbon to 5000 grains daily (see page 562). During the war every effort should be made to get bread and flour supplied in lieu of biscuit, and to supply red wine (page 307). As one of the perils of war is the occurrence of scurvy, the supply of fresh vegetables should be increased; if these at all fail during the campaign, the preserved vegetables must be issued, and the other precautions taken (see page 496). Considering the benefit apparently derived in Captain Cook's voyages from wort made from malt, it might be worth while to try the effect of introducing this as a beverage; it can be readily made.

Donald Monro mentions that at Bremen, in 1762, when no vegetables could be got, and fresh meat was dear, and scurvy broke out, infusion of horse-radish was found to be useful. Spruce beer was also used.

## SECTION III.

## ACTUAL WAR.[†]

Experience has showed in hundreds of campaigns that there is a large amount of sickness. The almost universality of this proves that, with every care, the conditions of war are unfavourable to health. The strenuous exertions, the broken rest, the exposure to cold and wet, the scanty, ill-cooked, or unwholesome food, the bad water, and the foul and overcrowded camps and tents, account for the amount of disease.

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[*] The examples are numerous, but the following are often quoted. In 1805 the French army broke up at Boulogne, and marched 400 leagues (French) to fight at Austerlitz; the youngest soldier was twenty-two years old; they left scarcely any sick or wounded *en route*. In 1809 the French marched from the German provinces to Vienna; not half the army were aged twenty years; the hospitals were filled with sick. In 1813 and 1814 the despatches of Napoleon are filled with complaints of the "boys" who were sent him, and who died in multitudes by the road side and in the hospitals.

[†] *Sanitary Rules of the Romans during War.*

Vegetius (*De Re Militari*, lib. iii. cap. 2) says the Romans took great care that the men should be well supplied with good water, good provisions, firewood, sufficient quantity of wine, vinegar, and salt. They endeavoured to keep their armies in good health by due attention—

1. To Situation; avoiding marshes and dry uncovered ground in summer; in having tents, frequently changing camps in summer and autumn.

2. To the Water; for bad water was considered to be very productive of diseases.

3. To the Seasons; not exposing men to heat. In winter, taking particular care that the men never were in want of firewood or of clothing.

The amount of illness varies with the nature of the campaign and the genius of the commander.

If the records can be trusted, it would seem that the English have been more unhealthy than the French in their wars, but there is no great trust to be placed in war statistics. In the Peninsula the mean daily number of sick was never below 12 per cent., except for a short time, in the lines of Torres Vedras, when it fell to 9 or 10. Sometimes it amounted to 15, 20, or 25 per cent. In the Crimea the immense sickness of the first winter is but too well remembered.

### *Army Medical Regulations.*

Before an army takes the field, the Director-General may appoint a medical officer to act as Field-Inspector under the principal medical officer, but not to act as sanitary officer. The Director-General prepares lists of all medicines, stores, &c. The amount of transport and of stores is laid down.

Before an army takes the field the Director-General, on requirement by the War Office, gives an account of everything in the proposed scene of operations which may affect the health of the men. He appoints a sanitary officer to be attached to the Quartermaster-General's department. He issues instructions to the principal medical officer and sanitary officer on all matters connected with rations, clothing, shelter, precautions for preventing disease, &c.

The sanitary officer inspects all proposed encamping ground, quarters, &c., and supervises the sanitary arrangements of all camps, towns, hospitals, &c. The principal medical officer advises the Commander of the Forces on all matters affecting health, such as rations, shelter, clothing, &c., and may, with the sanction of the Commander of the Forces, issue instructions on such matters to the medical officers.

The sanitary officer inspects the camp daily; accompanies the Quartermaster-General on the march, and gives his advice on all sanitary points. He is supplied with information to aid him in his work from all principal medical officers of general hospitals, divisions, and brigades in the field. He transmits a weekly sanitary report to the principal medical officer.

### *Causes of Sickness and Mortality in War.*

The chief causes of sickness and mortality in the English army have been in order of fatality—

1. Diseases arising from improper and insufficient food, viz., general feebleness and increased liability to malarious fevers, dysentery, diarrhœa, &c., and production of scurvy and scorbutic dysentery.

2. Malarious disease from unhealthy sites.

3. Catarrhs, bronchitis, pleurisy, pneumonia, rheumatism, dysentery (?), produced by inclemencies of weather.

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4. To Food and Medicine; the officers saw that the men had their regular meals, and were well looked after by the commissariat.

5. To Exercise; by keeping the troops during the day-time in constant exercise; in dry weather in the open air; in time of rain or snow under cover; for exercise was believed to do a great deal more for the preservation of health than the art of physic.

The Præfectus-Castrorum (Quartermaster-General), an officer of high rank in the Roman army, looked after the sick, and provided everything required by the surgeons. Both Livy and Tacitus mention that the commanding officers used to visit the sick and wounded soldiers, to inquire if they were well taken care of. The great health of the Roman soldiers was evidently owing to their great temperance; their excellent warm tents made of hides; their carefully kept camps; the warm war dress or sagum, and their constant exercise.

*Rules of the Macedonians.*—The only notice, I believe, of the means by which Alexander the Great preserved so wonderfully the health of his small army, is a statement that he frequently changed his encamping grounds (Quintus Curtius, lib. v. 32). This great soldier must certainly have been acquainted with the art of Hygiene.

4. Spotted typhus, kept up and spread (if not produced) by overcrowding and uncleanliness.
5. Contagious dysentery, arising from foul camps and latrines.
6. Typhoid and perhaps other fevers, produced by foul camps.
7. Exhaustion and debility, produced by excessive fatigue—a very great predisposing cause of almost all other diseases.
8. Cholera, in India especially, and in Turkey.
9. Yellow fever in the West Indian campaigns.
10. Plague in Egypt.
11. The exanthemata occasionally.
12. Ophthalmia.
13. Venereal diseases.

Of these diseases the most fatal have been scorbutic dysentery and typhus. It is indeed curious to see how invariably in all wars the scorbutic taint occurs, and frequently in how early a period of the campaign it can be detected. There almost seems to be something in the fatigues and anxieties of war which assists its development. It frequently complicates every other disease, impresses on them a peculiar character, and renders them very intractable to treatment. This is the case with dysentery, typhoid fever, malarious fever, and spotted typhus. With the last disease, especially, it has intimate relations, and contributes apparently to its propagation by rendering the frame more easily attacked by the specific poison.

One of the most important preventive measures to be adopted in war is the prophylactic treatment of scurvy. But with a full knowledge of this, the disease cannot always be avoided. The Federal Americans were fully aware of the necessity of combating it, and made immense efforts to do so. They did not succeed, and so marked and so general was the scorbutic taint in their army, that its combinations with typhoid fever and malaria have been looked upon as new diseases.

If scurvy could be prevented, every other war disease would be comparatively trifling. Inflammations from exposure, exhaustion from fatigue, and gastro-intestinal affections from improper food and atmospheric vicissitudes, would still occur; but the ravages of typhus, typhoid fever, malaria, and dysentery, would be trifling and easily prevented.

To prevent scurvy, then, is one of the most important measures.

If scurvy be absent, typhus fever is readily treated; isolation and the freest ventilation are certain to stop it. The only great danger would be in a besieged and crowded fortress. In such a place it may be beyond control, but early recognition and prompt isolation, as far as it can be done, and as free ventilation as possible, may perhaps stop it. It is in such cases that we should freely use the nitrous acid fumes and other disinfectant vapours.

Enteric (typhoid) fever and contagious dysentery, in the same way, ought with certainty to be prevented in a camp. The first case, even, should make us take urgent measures for the cleansing of latrines, or, better still, the closing of all the old and the opening of fresh ones. But the best plan of all is to shift the encamping ground, and we should remember the old Roman maxim, based doubtless on observation of typhoid fevers, that this must be done more often in the autumn.

The exanthemata, measles, and scarlet fever, sometimes spread largely through an army; the only plan is to separate all cases, and send them one day's march on the flank of the army, if it can be done, not in the direction of the line of supplies.

Plague probably demands the same measures as typhus.

The measures for cholera have been already sufficiently noted.

The diseases of exposure can be hardly avoided, but may be lessened by warm clothes and waterproof outer coverings. Flannel should be used next the skin all over the trunk and extremities, and is indispensable. One of the most important means to enable troops to stand inclemencies of weather, and indeed all fatigues, is hot food. Coffee and tea are the best, and hot spirits and water, though useful as an occasional measure, are much inferior, if indeed they do any good at all apart from the warmth. But the supply of *hot* food in war should be carefully attended to, especially in the case of breakfast, after which men will undergo without harm great exposure and fatigue.

It is unnecessary to enter at greater length into the measures to prevent the diseases of war, for the proper plans have been all enumerated previously. We may conclude only that much can be done to prevent disease, but we must also remember that the course of campaigns sometimes is too violent and overpowering for our efforts, and that wars, like revolutions, will never be made with rose water.

### *Recapitulation of the Duties of a Sanitary Officer during War.*

To go forward with the officers of the quartermaster's department, to choose the camping ground; arrange for surface drainage; if necessarily in a malarious place, make use of all obstacles, as hills, trees, &c., to throw off the malaria from the tents; place the tents with the openings from the malarious quarter. If possible, never take low hills (100 to 250 feet) above marshy plains. Arrange for the water supply, and for the service of the men, animals, and washing. As soon as possible fix the sites for the latrines; have them dug out, and make dry paths to them. As soon as the tents are pitched, visit the whole camp, and see that the external ventilation is not blocked in any way, and that the tents are as far off each other as can be permitted. Assign their work to the scavengers, and mark out the places of deposit for refuse. The daily inspection should include all these points, as well as the inspection of the food and cooking and of the slaughter-houses. If the camp be a large one, a certain portion should be selected every day for the careful inspection of the individual tents, but it should be made in no certain order, that the men may not prepare specially for the inspection.

A set of rules should be drawn up for the men, pointing out the necessity of ventilation, cleanliness of their persons, tents, and ground around them, and ordering the measures which are to be adopted. This will have to be promulgated by the general in command.

In the daily work, a certain order and routine should be followed, so that nothing shall be overlooked.

The sanitary officer of a large camp can never perform his duties without the most unremitting support from the regimental medical officers, who are the sanitary officers of their regiments. Not only must they inspect their own regimental camps, but by an immediate report to the sanitary officer of any disease which can possibly be traced to some camp impurity, they should render it possible for the commencing evil, of whatever kind, to be detected and checked.

As early as possible every morning the number of men reported sick from each regiment should be made known, and a calculation made of sick to strength, and then, if any regiment showed any excess of sick, the sanitary state of its camp should be specially and thoroughly investigated.

### *Hospitals in War.**

With an army in the field, hospitals are of several kinds.

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* Sir James M'Grigor, in the Peninsula, established divisional hospitals in front, and con-

1. The principal General Hospital at the base of operations.
2. The Intermediate Hospitals, divided into—
   - *a.* The Field Hospitals stationed at the base or on the line of communication.
   - *b.* The Field Hospitals proper, which move with the corps, and include the *dressing stations* and *regimental stations.*

The old *Regimental Hospital* is now definitively abolished, but medical and surgical assistance is provided by a medical officer with one or two attendants, accompanied by bearers, with stretchers when required, as in action in the field. The sick are treated in the field hospitals first, and then passed on to the intermediate hospitals in rear, which are again evacuated, as occasion requires, by transfer of patients to the principal general hospital at the base. This last will be in a convenient station on the frontier, or, in case of an insular nation like ourselves, on some sea-coast easily accessible. It is from it that men will ultimately be invalided home if unfit for further service.

For each army corps (of nominally 36,000 men) 25 field hospitals are appointed,—12 to move with the corps, and 13 to be stationed at the base and along the lines of communication,*—each is equipped for 200 sick, and may be divided into half hospitals for 100 each, if necessary. Slight cases would be treated in the field hospitals, but all cases likely to take any time should be sent to the rear of operations as soon as possible. Cases of fever (typhus and typhoid) ought to be removed as soon as possible far from the field force. It is of great importance that they should not be put near surgical cases, which ought to be kept separate, or mixed only with non-communicable diseases. This (the separation of fever from surgical cases) was a Peninsular rule of Sir James M'Grigor, and should never be forgotten. Ophthalmic cases ought also to be isolated.

The hospitals in rear may be at some distance, but connected either with a railway or by water carriage. It is of great importance to keep continually sending patients from the division and general hospitals with the army to the hospitals in rear. It is not only to keep the hospitals in front empty for emergencies, and to facilitate all movements of the army, but it has a great effect on the army itself. A great hospital full of sick is a disheartening spectacle, and often damps the spirits of the bravest men. The whole army is higher in hope and spirits when the sick are removed, as was shown remarkably by the Austrian experience of 1859. The sick themselves are greatly benefited by the removal; the change of scene, of air, of ideas, has itself a marvellous effect, and this is another great reason for constantly evacuating the sick from the hospitals in front.

The men who are reported for hospital in war must be divided into several classes—

1. Slightly wounded should be treated in the field or intermediate hospitals, and then return to duty.

2. Severely wounded at first in the field hospitals, then sent to the intermediate hospital, and then to the rear, as convalescence is always long.

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valescent hospitals in the rear, where the men were received *en route* to the depôt. Although he does not describe his system fully in his paper in the Medico-Chirurgical Transactions (vol. vi.), it is evident from his Autobiography that his constant practice was to send off the sick as soon as possible. This is shown by his narrative of the retreat from Burgos, when he saved Lord Wellington from the mortification of abandoning his sick and wounded to the enemy. My colleague, Professor Longmore, in his most instructive work on Transport, has detailed at length the means of transport of the sick and wounded, and other important matters of the kind.

* For full details of the new Hospital organisation in the field, see Professor Longmore's work, Gunshot Injuries, (1877) sect. ix. chap. 1.

3. Slight colds, diarrhœa, &c., treated in the field hospitals.

4. Severer colds, bronchitis, pleurisy, pneumonia, dysentery, &c., should be sent at once to the intermediate hospital, and then to the rear as soon as they can move with safety.

5. Typhus fever at once to the hospitals in rear, if possible without entering the field hospitals.

6. Typhoid cases, also, should be sent to the rear, and, in fact, all severe cases. The field hospitals should be always almost empty, and ready for emergencies.

These hospitals in rear may be even two or three days' journey off, if conveyance be by water, or one or two days if by rail. Sick and wounded men bear movement wonderfully well, with proper appliances, and are often indeed benefited.[*]

The proper position for these hospitals, at the base of operations, must be fixed by the commander of the forces at the commencement of the campaign, as he alone will know what point will be the base of supplies, and it is of importance to have these great hospitals near the large stores which are collected for the campaign.

It seems now quite clear that these hospitals should not be the ordinary buildings of the country adapted as hospitals. Such a measure seldom succeeds, and the mere adaptation is expensive, though probably always imperfect.[†] Churches should never be taken, as they are not only cold, but often damp, and there are often exhalations from vaults.

The French, Austrian, and American experience is in favour of having the hospitals in rear made of tents or wooden huts. The huts are perhaps the best, especially if the winter be cold. They were very largely used by the Federal Americans, who have entirely given up converting old buildings into hospitals. The best huts which were used in the Russian war of 1854–56 were those erected at Renkioi from Mr Brunel's design; each held fifty men in four rows. This plan, however, is not so good a one as having only two rows of beds. Hammond [‡] states that in the American war the best size has been found to be a ward for fifty men with two rows of beds; length of ward, 175 feet; width, 25; height, 14 feet; superficial area per man, 87 feet; cubic space per man, 1200 feet. Ventilation was by the ridge, an opening 10 inches wide, running the whole length, and by openings below, which could be more or less closed by sliding doors. Some of the American hospitals held from 2000 to 2800 beds.[§] It is probable, however, that smaller wards (for 25 men) would be better.

An hospital constructed of such huts can be of any size, but there must be several kitchens and laundries if it be very large. If space permit, however, it seems desirable to have rather a collection of smaller hospitals of 500 beds each, separated by half a mile of distance, than one large hospital.

The arrangement of the huts must be made according to the principles already laid down. Dr Hammond writes thus of these hospitals:—

"It will, perhaps, not be out of place again to insist on the great advantages of these temporary field hospitals over those located in permanent buildings in towns. Nothing is better for the sick and wounded, winter and summer, than a tent or a ridge-ventilated hut. The experience gained during the present war establishes this point beyond the possibility of a doubt. Cases of erysipelas or of hospital gangrene occurring in the old buildings, which were at one time unavoidably used as hospitals, but which are now almost displaced for the ridge-ventilated pavilions, immediately commenced to get well as soon as removed to the tents. But in one instance that has come to my knowledge has hospital gangrene originated in a wooden pavilion hospital, and in no instance, as far as I am aware, in a tent. Hospital gangrene has been exceedingly rare in all our hospitals, but two or three hundred cases occurring among the many wounded, amounting to over 100,000 of the loyal and rebel troops which have been treated in them. Again, wounds heal more rapidly in them, for the reason that the full benefit of the fresh air and the light are obtained. Even in fractures the beneficial effects are to be remarked." ("On Hygiene," p. 397.)

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[*] On this and other points of the like kind, see Report on Hygiene, in the Army Medical Report for 1862, pp. 349, 350.

[†] Donald Monro says that, in 1760, the houses in Germany taken for the sick were improved by taking away the stoves and putting in open fire-places. In the Peninsula, the Duke of Wellington appeared to have a dread of fever attacking the army. Luscombe tells us that the Duke asked the principal medical officer every day as to the appearance of fever. He also improved the hospitals by ordering open fire-places. (Luscombe, p. 6.)

[‡] On Hygiene, p. 355.

[§] See Report on Hygiene, in the Army Medical Report for 1862, p. 345, et seq., for a fuller description.

Baron Larrey, in his useful work,* describes the plans adopted by the French in the Italian war of 1859. At Constantinople, during the Crimean war, the French were apparently very well installed; the best buildings in Constantinople were assigned to them, and they were arranged with all the accuracy of organisation which distinguishes the French. The results were not, however, favourable, especially in the spring of 1856, when typhus spread through many of the hospitals, and caused great mortality.† Taught by this experience, in the Italian war of 1859 the French distributed their sick in small hospitals whenever they could find a building, and in this way the extension of the specific diseases was entirely stopped.

In the great Franco-Prussian war of 1870–71, the Germans made great use of temporary hospitals, and distributed their sick and wounded over almost the whole of Germany. The plans were very similar to those used in the Crimean and American wars. In some of the large cities, as at Berlin, immense hospitals, with railways and every appliance, were fitted up. The experience as regards hospital gangrene and erysipelas was favourable, but there were many cases of pyæmia in some of these hospitals.‡

To sum up, the hygiene of field hospitals in war (the rules are derived from our own Crimean experience, and that of the wars which have taken place since) is as follows:—The field, including the intermediate, hospitals to be made of tents; the tents being well constructed, of good size, thoroughly ventilated, the flaps being able to be raised so as almost, if desired, to make the tent into an awning. The most convenient and best are the hospital marquees of the new pattern, except for their considerable weight. The new double circular tents will now be used in all probability: they are a great improvement on the old bell-tent, and lighter than the marquee. Each weighs 100 ℔ dry, and four patients are put in a tent. For operating purposes, the central pole can be removed and a tripod support substituted, so as to leave the centre free.

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* Notice sur l'Hygiène des Hopitaux Militaires, 1862.

† Larrey mentions some striking instances of the effects of overcrowding. At Rami-Tchifflick, the hospital was fixed for 900 by the surgeon in charge, who allowed no more; it remained healthy. His successor increased the beds to 1200 and then to 1400. Typhus became most severe, and spared no one (ni infirmiers, ni sœurs, ni médecins). In the hospital at Pera there was the same mistake, and the same results. Typhus caused fifty per cent. of the deaths. At the hospital of the Ecole Militaire no crowding was permitted, and typhus caused only ten per cent. of the deaths. In the French ambulances in the Crimea the same facts were noticed. Double and treble numbers were crowded into some, and they were ravaged by typhus; others were not allowed to be crowded, and had little typhus.

‡ Numerous works have been published, which space does not allow me even to enumerate, but the medical officer will find much information in the Army Medical Department Reports, especially in the essays from the officers who were sent to France during the war.

The ground round the tents to be thoroughly drained, kept very clean, and replaced from time to time. The tent floor to be covered with clean, and, if possible, *dried* earth, or charcoal, and to be then covered with a waterproof cloth, or boarded, if the camp be one of position. In either case the greatest care must be taken that the ground does not get soaked and filthy. Every now and then (if possible every ten days or so) the tents should be shifted a little.

If it can be done, the sick should be raised off the ground. Iron bedsteads are cumbrous, but small iron pegs stuck in the ground might carry a sort of cot or hammock. The advantage of a plan of this kind is, that by means of holes in the sacking, wounded men can have the close-stool without much movement. For fever cases it permits a free movement of air under the patient.

The stationary general hospitals in rear should be of tents or wooden huts, but never of converted buildings, or of hospitals used by other nations. Here, of course, iron bedsteads, and all the appurtenances of a regular hospital, are brought into play.

Whenever practicable, the rear hospital should have water-closets and sewers. At Renkioi, in Turkey, Mr Brunel supplied square wooden sewers about fifteen inches to the side; they were tarred inside, and acted most admirably, without leakage, for fifteen months, till the end of the war. The water-closets (Jenning's simple syphon), arranged with a small water-box below the cistern to economise water, never got out of order, and, in fact, the drainage of the hospital was literally perfect. I have little doubt such well-tarred wooden sewers would last two or three years.

There is one danger about wooden hospitals, viz., that of fire. The huts should, therefore, on this ground alone, be widely separated; each hut should have, about ten feet from it, an iron box for refuse. Wooden boxes do not answer, as in the winter live cinders get thrown in, and there is danger of fire. These boxes should be emptied every morning by the scavengers. Water must be laid on into every ward.

The arrangement of the buildings is a simple matter, but must partly be determined by the ground. Long open lines are the best. An hospital of this kind, completely prepared in England, can be put up at a very rapid rate,* supposing there be no great amount of earth-work, and that the supply of water and of outlet for sewage be convenient. So that, if commenced at once at the beginning of a campaign, accommodation would soon be provided.

Circumstances may of course render it necessary to take existing buildings for hospital purposes, but it ought always to be remembered that it is running a very great risk, and nothing but rigid necessity ought to sanction it.

### *Laundry Establishment.*

This part of an hospital must be organised as early, and as perfectly, as possible. The different parts must be sent out from England, viz., boiler, drying-closet, washing-machines, and wringing-machines. The washing in war can never be properly done by the people among whom the war is carried on. Every appliance to save labour must be used, and after calculating what amount of laundry work has to be done for a presumed number of sick, just twice the amount of apparatus should be sent out, partly to insure against breakage, partly to meet moments of great pressure. The drying closet, especially, is a most important part of the laundry, as its heat can be used to disinfect.

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* The hospital at Renkoi, in Turkey, in the Crimean war, was made of such large huts (50 men in each) that its rapidity of erection is no guide to others; yet it was marvellously soon put up. The first beam was laid on the 24th May 1855, on the 12th July it was reported ready for 300 sick, every ward having water laid on, baths and closets, and an iron kitchen and laundry being also ready; on the 11th August it was ready for 500, and on the 4th December for 1000 sick. In January 1856 it was ready for 1500 sick, and in a short time more 2200 could have been received. The number of English artisans were only forty, but we had native workmen, and if we had had eighty English artisans it would have been ready for 1000 sick in three months. Smaller huts could be put up in much less time if the ground requires no terracing.

### *Amount of Hospital Accommodation.*

This must not be less than for 25 per cent. of the force, with reserve tents in rear in case of need.

Cemeteries in war must be as far removed as possible; the graves dug deep, and peat charcoal thrown in if it can be procured. Lime is generally used instead, but is not quite so good. If charcoal cannot be got, lime must be used. If the army is warring on the sea-coast, burial in the sea is the safest plan.

### *Flying Hospitals.*

For moving columns and excursions, flying hospitals are organised. Medical comforts, concentrated foods, wine, brandy, dressing instruments, bedding, &c., and perhaps tents, are carried in light carts, or on mules, or camels. If it can be done, an old recommendation of Donald Monro seems useful, viz., that a baker with flour should accompany, and even a butcher with live stock; but since the use of concentrated foods, the last is perhaps less needed.

### *Sanitary Duties connected with a War Hospital.*

In addition to the usual sanitary duties of an hospital, there are one or two points which require particular attention in the field.

The first of these is the possible conveyance of disease by the exceedingly dirty clothes, which may perhaps have been worn for weeks even without removal, in the hard times of war. Typhus, especially, can be carried in this way.

To provide for this, every hospital should have a tent or building for the reception of the clothes; here they should be sorted, freely exposed to air, and the dirty flannels or other filthy clothes picked out. Some of these are so bad that they should at once be burnt, and the principal medical officer, at the beginning of a campaign, should have authority given him to do this, and to replace the articles from the public store.

The articles which are not so bad should be cleansed. The cleansing is best done in the following way:—If the hospital have a laundry and drying closet, they should be put first in the drying-closet for an hour, and the heat carried to 220° Fahr. Then they should be transferred into the fumigation box; this is simply a tin-lined box or large chest. The clothes are put in this, and sulphur placed above them is set on fire, care being taken not to burn the clothes; or nitrous acid fumes should be used. After an hour's detention in the fumigating box, they should be removed to the soaking tubs. These are large tubs with pure water, put in a shed or tent outside the laundry. A little chloride of lime can be added to the water. They should soak here for twenty-four hours, and then go into the laundry and be washed as usual. This plan, and especially the heating and fumigation, will also kill lice, which often swarm in such numbers.

Another point of importance is to bathe the men as soon as possible. The baths of a war hospital at the base of operations should be on a large scale, and the means for getting hot water equally large. The men's heads, if lousy, should be washed with a little weak carbolic acid, which kills the lice at once. The smell is not agreeable, but that is not of real consequence.

In a war hospital, also, the use of charcoal in the wards, charcoal dressings, the employment of disinfectants of all kinds, is more necessary than in a common hospital.

As a matter of diet, there should be a large use in the diet of antiscorbutic food, vegetables, &c., and antiscorbutic drinks should be in every ward, to be taken *ad libitum*—citric acid and sugar, cream of tartar, &c. The bread must be very good, and of the finest flour, for the dysenteric cases.

The sanitary duties during sieges are often difficult. Water is often scarce, disposal of sewage not easy, and the usual modes of disposal of the dead cannot, perhaps, be made use of. If sewage is not washed away, and if there is no convenient plan of removing it by hand, it must be burnt. Mixing it with gunpowder may be adopted if there is no straw or other combustible material to put with it.

If food threaten to run short, the medical officer should remember how easily Dr Morgan's process of salting meat can be applied (see page 206), and in this way cattle or horses which are killed for want of forage, or are shot in action, can be preserved. For sieges, as vegetables are sure to fall short, a very ample supply of lemon-juice, and of citric acid, citrates, and cream of tartar, should be laid in, and distributed largely.

One other point should be brought to the notice of the general in command. In times of pressure, every man who can be discharged from the hospital is sent to the front. This cannot always be avoided. But when there is less pressure, the men should go from the rear hospitals to a depôt, and while there should still be considered under medical treatment, so that they may not too soon be subjected to the hardships of war. They should, in fact, be subjected again to a sort of training, as if they were just entering on the war. If this is not done, a number of sickly or half-cured men get into the ranks, who may break down in a moment of emergency, and cause great difficulty to the general in command. Some officers think that a man should either be in hospital or at his full duty ; this seems to me a misapprehension both of the facts and of the best way of meeting them. To transfer a man just cured, from the comforts of an hospital at once to the front, is to run great danger. A depôt, which should be a sort of convalescent hospital, though not under that term, is the proper place to thoroughly strengthen the man just recovered for the arduous work before him.

# APPENDIX A.

## METRICAL WEIGHTS AND MEASURES.

### *a. Length.*

1 Metre = 39·37 English inches = 3·28 feet.
1 Decimetre = 3·94 „ „ = (4 inches nearly.)
1 Centimetre = 0·39 „ „ = ($\frac{4}{10}$th inch nearly.)
1 Millimetre = 0·039 „ „ = ($\frac{1}{25}$th inch nearly.)

N.B.—The *Latin* prefix indicates division.
The *Greek* do. do. multiplication.

1 Kilometre = 1000 metres = 1094 yards = $\frac{5}{8}$th mile (nearly.)

### *b. Area.*

1 Square Metre = 10·76 sq. feet = 1542 sq. inches.
1 Square Centimetre = 0·154 sq. inches = $\frac{2}{13}$ sq. inch (nearly.)
1 Square Millimetre = 0·0015 „ = $\frac{1}{650}$ „ (nearly.)
100 Square Metres = 1 are = 119·7 square yards.
100 Ares = 1 hectare = 11967· „ „ = 2·47 acres.
100 Hectares = 1 square kilometre = 247 acres = 0·386 sq. mile.

### *c. Capacity.*

1 Decimetre cubed = 1 litre = 1000 cubic centimetres = 61 cubic inches = 35·3 ounces = 0·22 gallon.
1 Cubic centimetre = 0·061 cubic inch.
1 Cubic inch = 16·4 cubic centimetres.
28·35 Cubic centimetres = 1·733 cubic inches = 1 ounce.
1,000,000 cubic centimetres = 1000 litres = 1 cubic metre = 1 stere = 35·3 cubic feet.

### *d. Weight.*

1 Cubic centimetre of distilled water at 4° C. (39°·2 F.) weighs 1 gramme.
1 Gramme = 15·432 grains.
1 Decigramme = 1·543 „ (= 1½ grains nearly.)
1 Centigramme = 0·154 „ (= $\frac{2}{13}$ grains nearly.)
1 Milligramme = 0·015 „ (= $\frac{1}{65}$ grains nearly.)
1 Kilogramme = 1000 grammes = 15,432 grains = 2·2 lbs. *avoir.* = 35·3 ounces
French *livre* and German *pfund* = 500 grammes = 1·1 lbs. = 17·6 ounces.
The German *loth* = 16⅔ „ = ⅗ ounce nearly.

# APPENDIX B.

## THERMOMETER SCALES.

$$\frac{\text{Centigrade}}{5} = \frac{\text{Réaumur}}{4} = \frac{\text{Fahrenheit}-32}{9}$$

| | Centigrade. | Réaumur | Fahrenheit |
|---|---|---|---|
| Mercury freezes at . . . . . . | −40·0 | −32·0 | 40·0 |
| Zero of Fahrenheit . . . . . . | −17·7 | −14·2 | 0·0 |
| Water freezes at . . . . | 0·0 | 0·0 | 32·0 |
| Water at its maximum density at . . | 4·0 | 3·2 | 39·2 |
| Mean temperature of London . . . | 10·2 | 8·2 | 50·4 |
| Mean temperature for specific gravities, &c. | 15·5 | 12 4 | 60·0 |
| Mean temperature of Calcutta . . | 25·8 | 20·6 | 82·0 |
| Mean temperature of the human body . | 38·5 | 30·0 | 98·4 |
| Alcohol boils at . . . | 78·3 | 62·7 | 173·0 |
| Water boils at . . . . . | 100·0 | 80·0 | 212·0 |
| Mercury boils at . | 360·0 | 288·0 | 680 0 |

# APPENDIX C.

## BAROMETER SCALES.

Standard pressure = 760 millimetres = 29·922 inches.
30 inches = 762 „
29·5 „ = 749 „
29· „ = 737 „
28·5 „ = 724 „
28· „ = 711 „
1 „ = 25·4 „

# APPENDIX D.

## STANDARD SOLUTIONS FOR VOLUMETRIC ANALYSIS.

1. *For chlorine.* Silver nitrate solution.

17 grammes of silver nitrate in 1 litre of distilled water.
1 CC. of solution = 0·00355 gms. = 3·55 milligrammes of chlorine.
" " = 0·00585 " = 5·85 " of sodium chloride.
" " = 0·00745 " = 7·45 " of potassium chloride.
" " = 0·00535 " = 5·35 " of ammonium chloride.
Short factor for chlorine in grains per gallon (if one litre of water be taken for experiment) = 0·2485, or the CC.'s of silver nitrate solution required for $\frac{1}{4}$ litre, represent grains per gallon of chlorine *nearly*.

2. *Hardness.* Soap solution.

Dissolve some soft soap (pharmacopœial) in diluted spirit, and graduate by means of this barytic solution.

| | |
|---|---|
| Nitrate of barium, . . . | 0·26 grammes. |
| Distilled water, . . . . | 1 litre. |

2·2 CC.s (or 22 *measures*) of standard soap solution produce a permanent lather with 50 CC.s of the above solution.
1 measure (= $\frac{1}{10}$ CC.) of soap solution = 0·00025 gm. = 0·25 mgm. of calcium carbonate.

(For other co-efficients see page 78.)

Correction for lather = −2 measures of soap.
Short factors (when 50 CC.s of water are taken for experiment.)

For degrees of Clark's scale (1:70,000) = 0·35.
" " Metrical " (1:100,000) = 0·50.

3. *Permanganate Solution for Oxidisable Matter.*

0·395 of potassium permanganate in 1 litre of water.
100 CC.s are exactly decolorised by 100 CC.s of *oxalic acid solution* (*c.*) (See No. 7.)
1 CC. of permanganate solution used with acid yields 0·10 milligramme of oxygen.
1 CC. of permanganate solution used with alkali yields 0·06 milligramme of oxygen.
1 CC. of permanganate solution exactly oxidises 0·2875 mgms. nitrous acid ($NO_2$.)
1 CC. of permanganate solution exactly oxidises 0·2125 mgms. hydrogen sulphide ($H_2S$.)
1 CC. of permanganate solution exactly oxidises 0·7000 mgms. iron (Fe.)
" " " " 0·9000 " ferrous oxide (FeO.)

4. *Ammonium Chloride Solution for Nesslerising.*

0·315 gramme of ammonium chloride in 1 litre of water.

This is the *strong* solution.

Take 100 CC.s of this solution and dilute to 1 litre.

This is the *standard* solution.

1 CC. = 0·01 milligramme of ammonia ($NH_3$) or 0·0082 mgm. of nitrogen.
In analysing for nitric acid 1 part of $NH_3 = 3{\cdot}71\ HNO_3$.

5. *Sulphuric Acid Solution for Carbonates in Water.*

Take 4·9 grammes *by weight* of pure $H_2SO_4$ and dilute to 1 litre.
1 CC. saturates 5 milligrammes of calcium carbonate.
" " 6·2 " of sodium "

6. *Alkaline solution for acidities.*

Take liquor sodæ or liquor potassæ of pharmacopœial strength, and dilute with 8 or 9 parts of distilled water.
Graduate with *oxalic acid solution* (*a.*) (See No. 7.)
1 CC. of standard alkaline solution = 6·3 milligrammes of oxalic acid.

(For other coefficients see page 279.)

7. *Oxalic Acid Solutions.*

*Solution* (*a.*) Take 6·3 grammes of crystallised oxalic acid, and dissolve in one litre of water.
10 CC.s exactly neutralise 10 CC.s of standard alkaline solution.
*Solution* (*b.*) Take 100 CC.s of *solution* (*a*), and add 180 CC.s of distilled water.
This makes the solution for testing the alkalinity of lime or baryta water.
1 CC. exactly neutralises 1 milligramme of lime (CaO.)
" " " 2·73 " of baryta (BaO.)
*Solution* (*c.*) Take 100 CC.s of *solution* (*a*), and add 700 CC.s of distilled water.

This is the solution for graduating the permanganate.

100 CC.s exactly decolorise 100 CC.s of permanganate in presence of sulphuric acid.

8. *Copper Solution* (*Fehling's*) *for Sugars.*

| | | |
|---|---|---|
| Take of pure copper sulphate, . . | 34·64 grammes. | *Dissolve.* |
| " Distilled water, . . . . . | 200· CC. | |
| Take also of tartrate of sodium and potassium, | 173· grammes. | *Dissolve.* |
| Solution of caustic soda (or caustic potash), . | 480· CC. | |

Mix the two solutions slowly, and dilute with distilled water to one litre.
1 CC. is reduced by 5 milligrammes of either glucose or inverted sugar.
1 CC. " 8·67 " of lactin (or milk sugar).

9. *Iodine Solution for Hydrogen Sulphide.*

Dissolve 6·35 grammes of iodine in 1 litre of distilled water by the aid of a little potassium iodide.

1 CC. = 0·85 milligrammes of $H_2S$.

If a litre of water be taken for examination, the short factor for cubic inches per gallon is 0·164.

Starch is used as the indicator.

### 10. *Solution of Iron for Colorimetric Test.*

Dissolve one gramme of pure iron wire in nitro-hydrochloric acid; precipitate the ferric oxide with ammonia; wash the precipitate; dissolve in a little hydrochloric acid, and dilute to 1 litre.

1 CC. = 1 milligramme of iron.

This is the strong solution.

For use it is diluted 1 to 100, so that

1 CC. = 0·01 milligramme of metallic iron.
1 CC. = 0·02696 „ of iron phosphate.

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